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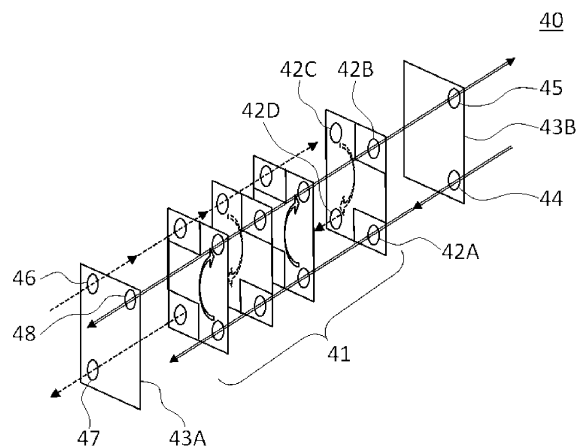
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(54) **PLATE HEAT EXCHANGER AND HEAT PUMP APPARATUS**

(57) A plate heat exchanger includes: a plurality of heat transfer plates in each of which first to fourth through-holes are provided to extend through the heat transfer plate in a single direction, and which are stacked together in the single direction and provided to isolate first and second water flow passages; and a pair of end plates in which first and second inlet ports, first and second outlet ports, and a connection port are provided, and which are provided such that the heat transfer plates are sandwiched between the end plates in the single direction. The first inlet port is continuous with the first

through-holes and allows a first fluid to flow into the first flow passage. The first outlet port is continuous with the second through-holes and allows the first fluid to flow out from the first flow passage. The second inlet port is continuous with the third through-holes and allows a second fluid to flow into the second flow passage. The second outlet port is continuous with the fourth through-holes and allows the second fluid to flow out from the second flow passage. The connection port is connected to a pressure relief valve provided separately from the plate heat exchanger.

FIG. 2



Description

Technical Field

[0001] The present disclosure relates to a plate heat exchanger and a heat pump apparatus.

Background Art

[0002] In the past, as a heat pump apparatus using a heat pump cycle, a heat pump apparatus that heats water to supply hot water or to condition air has been known. In such a heat pump apparatus, a water-refrigerant plate heat exchanger causes heat exchange to be performed between refrigerant that circulates in a refrigerant circuit and water that flows in a water circuit, thereby heating the water in the water circuit. At this time, the water may be expanded by heating. Therefore, in some cases, a pressure relief valve is provided in the water circuit (for example, see Patent Literature 1).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Patent No. 5246041 (paragraph 0017, Fig. 2)

Summary of Invention

Technical Problem

[0004] In the case where a water-refrigerant heat exchanger (plate heat exchanger) is damaged, and a water circuit (first flow passage, heat medium circuit) and a refrigerant circuit (second flow passage) communicate with each other, refrigerant (second fluid) higher in pressure than water (first fluid, heat medium) leaks to the water circuit. Normally, in the case where the refrigerant leaks to the water circuit, the pressure of the water circuit is raised. Therefore, in order to protect components and a pipe of the water circuit, a pressure relief valve of the water circuit is opened, thereby causing the water and the refrigerant to flow out from the pressure relief valve. At this time, the pressure of the refrigerant that has leaked to the water circuit becomes equal to the pressure of the water circuit, and the pressure in the water circuit becomes a set pressure of the pressure relief valve. It should be noted that depending on the set pressure of the pressure relief valve, a temperature of the refrigerant that has flowed into the water circuit and has been adiabatically expanded may fall below a freezing point of the water. In this case, the refrigerant whose temperature is lower than the freezing point of the water is mixed with the water, and the water is changed into ice. In addition, the pressure of the refrigerant is reduced, and the refrigerant receives heat from the water, whereby the refrigerant evaporates. Thus, a fluid in which minute ice is

mixed with refrigerant gas flows out from the pressure relief valve. When this state is maintained, the ice gradually adheres to a flow passage in the pressure relief valve to close the pressure relief valve, and may thus prevent the water and the refrigerant from flowing out from the pressure relief valve.

[0005] The present disclosure is applied in consideration of the above circumstances, and relates to a plate heat exchanger and a heat pump apparatus that can prevent the pressure relief valve from being closed, and can more reliably cause the second fluid that has leaked to the first flow passage, to flow out from the first flow passage through the pressure relief valve.

15 Solution to Problem

[0006] In a first aspect according to the present disclosure, a plate heat exchanger includes: a plurality of heat transfer plates in each of which a first through-hole, a second through-hole, a third through-hole, and a fourth through-hole are provided to extend through the heat transfer plate in a single direction, the plurality of heat transfer plates being stacked together in the single direction, configured to isolate a first flow passage through which a first fluid flows and a second flow passage through which a second fluid flows, and configured to cause heat exchange to be performed between the first fluid in the first flow passage and the second fluid in the second flow passage; a pair of end plates in which a first inlet port, a first outlet port, a second inlet port, a second outlet port, and a connection port are provided, the pair of end plates being provided such that the plurality of heat transfer plates are sandwiched between the pair of end plates in the single direction, the first inlet port being continuous with the first through-holes and located as a port through which the first fluid flows into the first flow passage, the first outlet port being continuous with the second through-holes and located as a port through which the first fluid flows out from the first flow passage, the second inlet port being continuous with the third through-holes and located as a port through which the second fluid flows into the second flow passage, the second outlet port being continuous with the fourth through-holes and located as a port through which the second fluid flows out from the second flow passage, the connection port being continuous with the first through-holes or the second through-holes, and branching off from the first flow passage. The connection port is connected to a pressure relief valve provided separately from the plate heat exchanger.

[0007] In a second aspect according to the present disclosure, a heat pump apparatus includes: a refrigerant circuit in which a compressor, a plate heat exchanger, an expansion mechanism, and a heat-source-side heat exchanger are connected by refrigerant pipes to circulate refrigerant; a heat medium circuit in which a pump, the plate heat exchanger, and a use-side heat exchanger are connected by heat medium pipes to circulate a heat

medium; and a pressure relief valve connected to a connection port that branches off from part of the heat medium circuit that is located in the plate heat exchanger, the pressure relief valve being provided separately from the plate heat exchanger.

Advantageous Effects of Invention

[0008] In the above plate heat exchanger, in the case where the plate heat exchanger is damaged, and as a result the first flow passage and the second flow passage communicate with each other, the pressure in the first flow passage is raised because of leakage of the second fluid to the first flow passage, and the pressure relief valve is opened. The pressure relief valve is connected to the connection port that branches off from the first flow passage, not the first inlet port located as a port through which the first fluid flows into the first flow passage or the first outlet port located as a port through the first fluid flows out from the first flow passage. This configuration thus causes the second fluid that has leaked to the first flow passage to flow out concentratedly from the pressure relief valve without being substantially mixed with the first fluid. It is therefore possible to prevent coagulation of the first fluid from closing the pressure relief valve, and thus more reliably cause the second fluid that has leaked to the first flow passage, to flow out from the first flow passage through the pressure relief valve.

[0009] In the above heat pump apparatus, in the case where the plate heat exchanger is damaged, and as a result, the refrigerant circuit and the heat medium circuit communicate with each other, the pressure in the heat medium circuit is raised because of leakage of the refrigerant to the heat medium circuit, and the pressure relief valve is opened. The pressure relief valve is connected to the connection port that branches off from the heat medium circuit in the plate heat exchanger. This configuration causes the refrigerant that has leaked to the heat medium circuit to flow out concentratedly from the pressure relief valve without being substantially mixed with the heat medium. Therefore, it is possible to prevent coagulation of the heat medium from closing the pressure relief valve, and thus more reliably cause the refrigerant that has leaked to the heat medium circuit, to flow out from the heat medium circuit through the pressure relief valve.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a schematic diagram illustrating a configuration of a heat pump apparatus according to Embodiment 1 of the present disclosure.

[Fig. 2] Fig. 2 is an exploded perspective view schematically illustrating a plate heat exchanger according to Embodiment 1 of the present disclosure.

[Fig. 3] Fig. 3 is a schematic front view illustrating

the plate heat exchanger.

[Fig. 4] Fig. 4 is a sectional view taken along line IV-IV in Fig. 3.

[Fig. 5] Fig. 5 is a schematic diagram illustrating a flow of fluid in the plate heat exchanger.

[Fig. 6] Fig. 6 is a schematic diagram illustrating the flow of the fluid in the plate heat exchanger in the case where refrigerant leaks.

[Fig. 7] Fig. 7 is a schematic diagram illustrating a configuration of a heat pump apparatus according to Embodiment 2 of the present disclosure.

[Fig. 8] Fig. 8 is a sectional view taken along line IV-IV in Fig. 3 in a state where a pressure relief valve is attached.

[Fig. 9] Fig. 9 is a schematic front view illustrating a plate heat exchanger according to Embodiment 4 of the present disclosure.

[Fig. 10] Fig. 10 is a sectional view taken along line X-X in Fig. 9.

[Fig. 11] Fig. 11 is a sectional view of a plate heat exchanger of a modification of Embodiment 4 that is taken along line X-X in Fig. 9.

Description of Embodiments

(Embodiment 1)

[0011] Embodiment 1 of the present disclosure will be described with reference to Figs. 1 to 6. In each of the figures, components that are the same as those in a previous figure or figures are denoted by the same reference signs.

[0012] Fig. 1 is a schematic view illustrating a configuration of a heat pump apparatus 1 according to Embodiment 1. As illustrated in Fig. 1, the heat pump apparatus 1 includes a refrigerant circuit 10 that causes refrigerant to circulate, a water circuit (heat medium circuit) 20 that causes water (heat medium) to circulate, and a pressure relief valve 30.

[0013] The refrigerant circuit 10 includes a compressor 12, a plate heat exchanger 40, an expansion valve (expansion mechanism) 13, and an air heat exchanger (heat-source-side heat exchanger) 14 that are connected by refrigerant pipes 11.

[0014] As the refrigerant that circulates in the refrigerant circuit 10, refrigerant that has a low ozone depleting potential (hereinafter referred to as "ODP") and a low global warming potential (hereinafter referred to as "GWP") is used in consideration of a load on an environment. As such refrigerant, for example, the following refrigerant is used: hydro fluorocarbon (HFC) refrigerant such as R32 that is lower in GWP than R410A and R407C; hydrofluoroolefin (HFO) refrigerant such as HFO-1234yf and HFO-1234ze; or hydrocarbon (HC) refrigerant such as propane and butane. These refrigerants have a low ODP and a low GWP, but are flammable. Furthermore, any of the refrigerants may be used as a single-component refrigerant, or two or more of the re-

frigerants may be mixed and used as mixed refrigerant

[0015] The compressor 12 compresses sucked low-pressure refrigerant into high-pressure refrigerant and then discharges the high-pressure refrigerant. In Embodiment 1, the compressor 12 includes an inverter device and other components, and a capacity (the amount of refrigerant that is sent per unit time) of the compressor 12 can be changed by arbitrarily changing a driving frequency.

[0016] The plate heat exchanger 40 causes heat exchange to be performed between the refrigerant that flows in the refrigerant circuit 10 and water that flows in the water circuit 20. A detailed configuration of the plate heat exchanger 40 will be described later.

[0017] The expansion valve 13 adjusts the flow rate of the refrigerant, and for example, adjusts (reduces) the pressure of the refrigerant that flows into the air heat exchanger 14. In Embodiment 1, the expansion valve 13 is an electronic expansion valve whose opening degree can be changed in response to an instruction from a controller not illustrated.

[0018] The air heat exchanger 14 causes heat exchange to be performed between the refrigerant that flows in the refrigerant circuit 10 and air (outside air) sent by a fan. In Embodiment 1, the air heat exchanger 14 is a fin-and-tube heat exchanger that is made of, for example, copper or aluminum.

[0019] In Embodiment 1, the heat pump apparatus 1 is configured such that in the refrigerant circuit 10, a normal operation and a defrosting operation can be performed. In the normal operation, water that flows in the water circuit 20 is heated, and in the defrosting operation, the refrigerant is caused to flow in the opposite direction to the flow direction of the refrigerant in the normal operation, to defrost the air heat exchanger 14. When the normal operation is performed under an environment in which the temperature of outside air is low, dew condensation water may freeze in the air heat exchanger 14, and frost may adhere to a surface of the air heat exchanger 14. The frost grows when the normal operation continues, and reduces the heat exchange efficiency of the air heat exchanger 14. Therefore, the defrosting operation is necessary for the environment in which the temperature of the outside air is low.

[0020] More specifically, in order to enable the normal operation and the defrosting operation to be performed, the refrigerant circuit 10 includes a four-way valve 15. The four-way valve 15 operates as a flow switching device, and switches the flow direction of the refrigerant in the refrigerant circuit 10 between that in the normal operation and that in the defrosting operation. Furthermore, during the normal operation, the plate heat exchanger 40 operates as a heat radiator (condenser) that heats the water that flows in the water circuit 20, and during the defrosting operation, the plate heat exchanger 40 operates as a heat receiving device (evaporator) that receives heat from the water that flows in the water circuit 20. The air heat exchanger 14 operates a heat receiving

device (evaporator) during the normal operation, and operates as a heat radiator (condenser) during the defrosting operation.

[0021] In Embodiment 1, the heat pump apparatus 1 includes an outdoor unit 51 that houses the compressor 12, the four-way valve 15, the plate heat exchanger 40, the expansion valve 13, and the air heat exchanger 14 of the refrigerant circuit 10. The outdoor unit 51 is installed in an outdoor space. Furthermore, the outdoor unit 51 includes a controller not illustrated that controls an operation of the refrigerant circuit 10. The controller controls, for example, driving of the compressor 12, switching of a flow passage by the four-way valve 15, the opening degree of the expansion valve 13, and air-sending by a fan provided in the air heat exchanger 14.

[0022] Next, an example of the operation of the refrigerant circuit 10 will be described with reference to Fig. 1. In Fig. 1, the flow direction of the refrigerant in the refrigerant circuit 10 during the normal operation is indicated by solid arrows, and the flow direction of the refrigerant during the defrosting operation is indicated by dashed arrows.

[0023] In the refrigerant circuit 10, during the normal operation, the flow passage for the refrigerant is changed by the four-way valve 15 to a flow passage indicated by solid lines, and high-temperature and high-pressure refrigerant flows into the plate heat exchanger 40. That is, during the normal operation, in the refrigerant circuit 10, the refrigerant circulates through the compressor 12, the four-way valve 15, the plate heat exchanger 40, the expansion valve 13, the air heat exchanger 14, the four-way valve 15, and the compressor 12 in this order.

[0024] The high-temperature and high-pressure refrigerant discharged from the compressor 12 while being in a gas state (that will hereinafter be referred to as "gas refrigerant") flows into a refrigerant flow passage (second flow passage) in the plate heat exchanger 40 through the four-way valve 15. In the plate heat exchanger 40, heat exchange is performed between the refrigerant that flows through the refrigerant flow passage and the water that flows in a water flow passage (first flow passage) in the plate heat exchanger 40, and condensation heat of the refrigerant is transferred to the water. As a result, the refrigerant that has flowed into the plate heat exchanger 40 is condensed to change into high-pressure refrigerant being in a liquid state (which will hereinafter be referred to as "liquid refrigerant"). The water that flows in the water flow passage of the plate heat exchanger 40 is heated by the heat transferred from the refrigerant.

[0025] The high-pressure liquid refrigerant condensed in the plate heat exchanger 40 flows into the expansion valve 13, and is reduced in pressure to change into low-pressure refrigerant being in a two-phase state (which will hereinafter be referred to as "two-phase refrigerant"). The low-pressure two-phase refrigerant flows into the air heat exchanger 14. At the air heat exchanger 14, heat exchange is performed between the refrigerant that flows in the air heat exchanger 14 and air (outside air) sent by

the fan. As a result, the refrigerant that has flowed into the air heat exchanger 14 receives heat from the air, and evaporates to change into low-pressure gas refrigerant. The low-pressure gas refrigerant is sucked into the compressor 12 through the four-way valve 15. The refrigerant that has been sucked into the compressor 12 is compressed into high-temperature and high-pressure gas refrigerant. During the normal operation, the above cycle is repeated.

[0026] During the defrosting operation, in the refrigerant circuit 10, the flow passage for the refrigerant is changed by the four-way valve 15 to the flow passage indicated by dashed lines, and the high-temperature and high-pressure refrigerant flows into the air heat exchanger 14. To be more specific, during the defrosting operation, in the refrigerant circuit 10, the refrigerant circulates through the compressor 12, the four-way valve 15, the air heat exchanger 14, the expansion valve 13, the plate heat exchanger 40, the four-way valve 15, and the compressor 12 in this order.

[0027] The high-temperature high-pressure gas refrigerant discharged from the compressor 12 flows into the air heat exchanger 14 through the four-way valve 15. In the air heat exchanger 14, since the refrigerant flows in the air heat exchanger 14, frost adhering to a surface of the air heat exchanger 14 is heated by condensation heat of the refrigerant and is melted. The refrigerant that has flowed into the air heat exchanger 14 is condensed to change into high-pressure liquid refrigerant. The liquid refrigerant that has flowed out of the air heat exchanger 14 flows into the expansion valve 13, and is changed into two-phase refrigerant, and the two-phase refrigerant flows into the plate heat exchanger 40. The two-phase refrigerant that has flowed into the plate heat exchanger 40 receives heat from water that flows through the water flow passage in the plate heat exchanger 40, and evaporates to change into the gas refrigerant. The gas refrigerant is sucked into the compressor 12 through the four-way valve 15, and is compressed into high-temperature and high-pressure gas refrigerant. During the defrosting operation, the above cycle is repeated.

[0028] In the water circuit 20, the pump 22, the plate heat exchanger 40, and a heating terminal (use-side heat exchanger) 23 are connected by water pipes (heat medium pipes) 21. The water that circulates in the water circuit 20 is, for example, pure water or tap water.

[0029] The pump 22 is a device that applies a pressure to the water in the water circuit 20, thereby causing the water to circulate in the water circuit 20. The heating terminal 23 is installed in a room (indoor space) and heats a space 60 that is an air-conditioned space. In Embodiment 1, the heating terminal 23 is, for example, a panel heater or a floor heating panel, and internally includes a heat exchange unit. Into this heat exchange unit, the water in the water circuit 20 that is heated at the plate heat exchanger 40 flows. At the heat exchange unit of the heating terminal 23, heat exchange is performed between air in the space 60 and the water that has flowed

into the heat exchange unit, and heat is transferred from the water to the air in the space 60. As a result, the space 60 is heated and the water is cooled.

[0030] In Embodiment 1, the water circuit 20 further includes an expansion tank 24 and a safety valve 25. The expansion tank 24 is a device configured to control within a predetermined range, a pressure that changes because of a volume change of the water in the water circuit 20 that is made by, for example, heating. The expansion tank 24 is connected to a pipe that branches off from the water pipe 21 connecting the pump 22 and the heating terminal 23. The safety valve 25 is provided as a protection device. In the case where the pressure in the water circuit 20 rises to exceed a pressure control range of the expansion tank 24, the safety valve 25 causes the water in the water circuit 20 to flow out from the water circuit 20 to the outside. The safety valve 25 is connected to a pipe that branches off from the water pipe 21 connecting the plate heat exchanger 40 and the heating terminal 23.

[0031] Furthermore, in Embodiment 1, the heat pump apparatus 1 includes an indoor unit 52 that houses the pump 22, the expansion tank 24, and the safety valve 25 that are provided in the water circuit 20. The indoor unit 52 is installed in the room (indoor space). The indoor unit 52 further includes a controller not illustrated that controls an operation of the water circuit 20, such as driving of the pump 22.

[0032] The pressure relief valve 30 is connected to the plate heat exchanger 40. More specifically, the pressure relief valve 30 is connected to a connection port 48 of the plate heat exchanger 40 that will be described below. The connection port 48 is provided in such a manner as to branch off (from part of the water circuit 20 that is located in the plate heat exchanger 40. In Embodiment 1, the pressure relief valve 30 is housed together with the plate heat exchanger 40 in the outdoor unit 51, and is located in the outdoor space. For example, when the refrigerant leaks from part of the refrigerant circuit 10 that is located in the plate heat exchanger 40 to the water circuit 20, and the pressure in the water circuit 20 exceeds a predetermined set value, the pressure relief valve 30 is automatically opened to cause fluid such as the water and the refrigerant to flow out from the water circuit 20 to the outside. As a result, when the pressure in the water circuit 20 drops to a value lower than or equal to the set value, the pressure relief valve 30 is automatically closed to stop the flow of the fluid from the water circuit 20 to the outside.

[0033] Next, the configuration of the plate heat exchanger 40 will be described with reference to Figs. 2 to 6. Fig. 2 is an exploded perspective view schematically illustrating the plate heat exchanger 40. Fig. 3 is a front view schematically illustrating the plate heat exchanger 40. Fig. 4 is a sectional view taken along line IV-IV in Fig. 3.

[0034] As illustrated in Figs. 2 and 4, the plate heat exchanger 40 includes a plurality of heat transfer plates

41 and a pair of end plates 43A and 43B.

[0035] The plurality of heat transfer plates 41 are stacked together in a predetermined direction (hereinafter referred to as "stacking direction"), isolate a water flow passage (first flow passage) through which water (heat medium, i.e., first fluid) flows and a refrigerant flow passage (second flow passage) through which the refrigerant (second fluid) flows, and cause heat exchange to be performed between the water in the water flow passage and the refrigerant in the refrigerant flow passage. In each of the heat transfer plates 41, four through-holes are formed to extend through the heat transfer plate 41 in the stacking direction. The four through-holes are a first through-hole 42A, a second through-hole 42B, a third through-hole 42C, and a fourth through-hole 42D. In Embodiment 1, each of the heat transfer plates 41 is formed in the shape of a substantially rectangular plate as viewed from the stacking direction, and the first through-hole 42A, the second through-hole 42B, the third through-hole 42C, and the fourth through-hole 42D are provided in respective four corners of each heat transfer plate 41 formed in the shape of the substantially rectangular plate. A surface of each heat transfer plate 41 is a heat transfer surface for heat exchange. In the heat transfer surface, for example, a plurality of waveforms that are offset relative to each other in the stacking direction and are V-shaped are provided. Each of the heat transfer plates 41 is made by, for example, pressing a metal plate such as a stainless steel plate.

[0036] The pair of end plates 43A and 43B are provided such that the plurality of heat transfer plates 41 are sandwiched between the end plates 43A and 43B in the stacking direction. In the end plates 43A and 43B, a first inlet port 44, a first outlet port 45, a second inlet port 46, a second outlet port 47, and a connection port 48 are provided. The first inlet port 44 is continuous with the first through-holes 42A of the heat transfer plates 41, and is used as a port through which the water flows from the water pipe 21 into the water flow passage. The first outlet port 45 is continuous with the second through-holes 42B of the heat transfer plates 41, and is used as a port through which the water flows from the water flow passage into the water pipe 21. The second inlet port 46 is continuous with the third through-holes 42C of the heat transfer plates 41, and is used as a port through which the refrigerant flows from the refrigerant pipe 11 into the refrigerant flow passage. The second outlet port 47 is continuous with the fourth through-holes 42D of the heat transfer plates 41, and is used as a port through which the refrigerant flows from the refrigerant flow passage to the refrigerant pipe 11. The connection port 48 is connected to the pressure relief valve 30. Furthermore, the connection port 48 is continuous with the second through-holes 42B of the heat transfer plates 41, and branches off from the water flow passage. In Embodiment 1, the connection port 48 is located continuous with the second through-holes 42B of the heat transfer plates 41 and also opposite to the first outlet port 45. In the

above description, in order to simplify the description, the flow of the refrigerant and the flow of the water are described with respect to the flows of the refrigerant and the water during the normal operation. Therefore, for example, during the defrosting operation, the refrigerant is caused to flow into the plate heat exchanger 40 through the second outlet port 47, and flow out from the plate heat exchanger 40 through the second inlet port 46.

[0037] In Embodiment 1, as illustrated in Figs. 2 to 4, each of the pair of end plates 43A and 43B is formed in the shape of a substantially rectangular plate as viewed from the stacking direction. In the end plate 43A, the second inlet port 46, the second outlet port 47, and the connection port 48 are provided in respective three of four corners of the end plate 43A, which correspond to the positions of the third through-holes 42C, the fourth through-holes 42D, and the second through-holes 42B of the heat transfer plates 41. In the end plate 43B, the first inlet port 44 and the first outlet port 45 are provided in respective two of four corners of the end plate 43B, which correspond to the positions of the first through-holes 42A and the second through-holes 42B of the heat transfer plates 41. In such a manner, the connection port 48 is provided in the end plate other than the end plate having the first inlet port 44 and the first outlet port 45. In addition, at the first inlet port 44, the first outlet port 45, the second inlet port 46, the second outlet port 47, and the connection port 48, respective cylindrical nozzles are provided.

[0038] The heat transfer plates 41 and the end plates 43A and 43B are stacked and joined together by, for example, brazing, such that each of the outer peripheral edges of each of the heat transfer plates 41 and the end plates 43A and 43B is aligned with corresponding ones of the outer peripheral edges of the others of the heat transfer plates 41 and the end plates 43A and 43B. As a result, the water flow passage and the refrigerant flow passage are provided between adjacent ones of the heat transfer plates 41. Furthermore, with the heat transfer plates 41 stacked together, the water flow passage and the refrigerant flow passage are alternately located in a plurality of spaces between the heat transfer plates 41, the first through-holes 42A and the second through-holes 42B communicate with the water flow passage, and the third through-holes 42C and the fourth through-holes 42D communicate with the refrigerant flow passage.

[0039] Fig. 5 is a schematic diagram illustrating the flow of the fluid in the plate heat exchanger 40. In Fig. 5, the flow of the water in the plate heat exchanger 40 is indicated by solid lines, and the flow of the refrigerant is indicated by dashed lines. During the normal operation, as indicated in Fig. 5, the water in the water circuit 20 flows from the first inlet port 44 into the plate heat exchanger 40, then flows through the water flow passage provided between the heat transfer plates 41, and flows out from the first outlet port 45. The refrigerant in the refrigerant circuit 10 flows from the second inlet port 46 into the plate heat exchanger 40, then flows through the refrigerant

flow passage provided between the heat transfer plates 41, and then flows out from the second outlet port 47. At this time, heat exchange is performed between the water that flows through the water flow passage and the refrigerant that flows through the refrigerant flow passage.

[0040] Next, an operation in the case where the refrigerant leaks to the water flow passage in the plate heat exchanger 40 will be described with reference to Fig. 6. Fig. 6 is a schematic diagram illustrating the flow of the fluid in the plate heat exchanger 40 in the case where the refrigerant leaks. In the plate heat exchanger 40, the heat transfer plates 41 may be damaged because of, for example, corrosion that occurs at the heat transfer plates 41 and metal fatigue caused by aged deterioration. Furthermore, for example, during the defrosting operation, in the plate heat exchanger 40, the refrigerant receives heat from the water and the water is thus cooled. At this time, in the case where the temperature of the water is low, the water that flows in the water circuit of the plate heat exchanger 40 may freeze. In this case, the heat transfer plates 41 may be deformed and broken because of volume expansion of the water that occurs when the water freezes.

[0041] During the normal operation, for example, the pressure of the water in the water circuit 20 is approximately 0.3 MPa, whereas the pressure of the refrigerant in the refrigerant circuit 10 at the time when the refrigerant flows into the plate heat exchanger 40 is approximately 1.0 MPa. The pressure of the refrigerant is higher than that of the water. Thus, in the case where the heat transfer plates 41 are damaged, and the water flow passage and the refrigerant flow passage communicate with each other at a communication portion A as indicated in Fig. 6, the refrigerant that flows in the refrigerant flow passage flows into the water flow passage through the communication portion A. Consequently, the pressure in the water flow passage rises. When the pressure in the water flow passage exceeds the set value of the pressure relief valve 30 connected to the connection port 48, the pressure relief valve 30 is opened.

[0042] The refrigerant that has flowed from the communication portion A into the water flow passage flows toward the pressure relief valve 30 while pushing water that is present between the communication portion A and the pressure relief valve 30, and thus causes the water to flow out from the pressure relief valve 30. After the water completely flows out, the refrigerant flows out from the pressure relief valve 30. At this time, there is a possibility that the refrigerant that has flowed from the communication portion A into the water flow passage may flow from the first inlet port 44 or the first outlet port 45 to the water circuit 20. However, actually, since the water is incompressible, the water prevents the refrigerant from flowing to the first inlet port 44 or the first outlet port 45. Furthermore, even in the case where the safety valve 25 is opened to allow the water and the refrigerant to flow out from the safety valve 25, the possibility with which the refrigerant will flow toward the safety valve 25 is very

low because a passage from the communication portion A to the safety valve 25 through the first outlet port 45 is far longer than a passage from the communication portion A to the pressure relief valve 30, and a pressure loss is increased. Therefore, after the pressure relief valve 30 is opened, the refrigerant substantially completely flows out from the pressure relief valve 30. On the other hand, since the connection port 48 connected to the pressure relief valve 30 is provided separately from the first inlet port 44 and the first outlet port 45, the water in the water circuit 20 that flows into the water flow passage can flow from the first inlet port 44 to the first outlet port 45 through the water flow passage even after the pressure relief valve 30 is opened. In addition, since the pressure of the water is lower than the pressure of the refrigerant that flows toward the pressure relief valve 30, the refrigerant prevents the water from flowing toward the pressure relief valve 30. Therefore, although water that is present between the communication portion A and the pressure relief valve 30 when the pressure relief valve 30 is opened flows out from the pressure relief valve 30, most of remaining water flows from the first outlet port 45 to the water circuit 20 without flowing out from the pressure relief valve 30. In such a manner, the refrigerant that has flowed from the communication portion A into the water flow passage concentratedly flows out from the pressure relief valve 30, with the water hardly mixed with the refrigerant.

[0043] For example, if the pressure relief valve is provided on a downward side of the water circuit in the plate heat exchanger as in an existing configuration, the refrigerant that has flowed into the water flow passage flows together with the water in the water flow passage from the first outlet port toward the pressure relief valve through the water pipe, and the refrigerant thus flows out together with the water from the pressure relief valve. Therefore, the water is cooled by the refrigerant to change into ice, and the ice adheres to the flow passage in the pressure relief valve to close the pressure relief valve. In contrast, in the configuration according to Embodiment 1, the refrigerant that has flowed from the communication portion A into the water flow passage concentratedly flows out from the pressure relief valve 30, with the water hardly mixed with the refrigerant, as described above. Furthermore, since the amount of water that flows out from the pressure relief valve 30 is small, even when the refrigerant that has flowed from the communication portion A into the water flow passage adiabatically expands and the temperature of the refrigerant falls below the freezing point of the water, the refrigerant does not close the pressure relief valve 30. It is therefore possible to prevent the pressure relief valve 30 from being closed, and thus possible to more reliably cause the refrigerant that has leaked to the water flow passage to flow out of the water flow passage through the pressure relief valve 30.

[0044] The heat pump apparatus 1 according to Embodiment 1 includes: the refrigerant circuit 10 in which

the compressor 12, the plate heat exchanger 40, the expansion valve 13, and the air heat exchanger 14 are connected by the refrigerant pipes 11 to cause the refrigerant to circulate; the water circuit 20 in which the pump 22, the plate heat exchanger 40, and the heating terminal 23 are connected by the water pipes 21 to cause the water to circulate; and the pressure relief valve 30 connected to the connection port 48 that branches off from part of the water circuit 20 that is located in the plate heat exchanger 40.

[0045] In the above configuration, in the case where the plate heat exchanger 40 is damaged, and the refrigerant circuit 10 and the water circuit 20 communicate with each other, the refrigerant leaks to the water circuit 20, the pressure in the water circuit 20 is thus raised, and the pressure relief valve 30 is opened. Since the pressure relief valve 30 is connected to the connection port 48 branching off from the part of the water circuit 20 that is located in the plate heat exchanger 40, the refrigerant that has leaked to the water circuit 20 concentratedly flows out from the pressure relief valve 30, with the water hardly mixed with the refrigerant. Thus, it is possible to prevent the water from being cooled by the refrigerant, and thus from changing into ice, that is, ice does not close the pressure relief valve 30. It is therefore possible to more reliably cause the refrigerant that has leaked to the water circuit 20, to flow out from the water circuit 20 through the pressure relief valve 30.

[0046] Furthermore, the plate heat exchanger 40 according to Embodiment 1 includes the plurality of the heat transfer plates 41 and the pair of end plates 43A and 43B. Each of the heat transfer plates 41 includes the first through-hole 42A, the second through-hole 42B, the third through-hole 42C, and the fourth through-hole 42D that extend through the heat transfer plate 41 in the stacking direction. The heat transfer plates 41 are stacked together in the stacking direction, isolate the water flow passage through which the water flows and the refrigerant flow passage through which the refrigerant flows, and cause heat exchange to be performed between the water in the water flow passage and the refrigerant in the refrigerant flow passage. The pair of end plates 43A and 43B include the first inlet port 44, the first outlet port 45, the second inlet port 46, the second outlet port 47, and the connection port 48, and are located such that the heat transfer plates 41 are sandwiched between the end plates 43A and 43B in the stacking direction. The first inlet port 44 is continuous with the first through-holes 42A and located as a port through which the water flows into the water flow passage. The first outlet port 45 is continuous with the second through-holes 42B and located as a port through which the water flows out from the water flow passage. The second inlet port 46 is continuous with the third through-holes 42C and located as a port through which the refrigerant flows into the refrigerant flow passage. The second outlet port 47 is continuous with the fourth through-holes 42D and located as a port through which the refrigerant flows out from the refrigerant flow pas-

sage. The connection port 48 is continuous with the second through-holes 42B, branches off from the water flow passage, and is connected to the pressure relief valve 30.

[0047] In the above configuration, in the case where the plate heat exchanger 40 is damaged and the water flow passage and the refrigerant flow passage communicate with each other, the refrigerant leaks to the water flow passage, the pressure in the water flow passage is thus raised, and the pressure relief valve 30 is opened. The pressure relief valve 30 is connected to the connection port 48 that branches off from the water flow passage, not the first inlet port 44 through which the water flows into the water flow passage or the first outlet port 45 through which the water flows out from the water flow passage. Thus, the refrigerant that has leaked to the water flow passage concentratedly flows out from the pressure relief valve 30, with the water hardly mixed with the refrigerant. Therefore, it is possible to prevent the water from being cooled by the refrigerant, that is, prevent the water from changing into ice. According, it is possible to prevent ice from closing the pressure relief valve, and thus possible to more reliably cause the refrigerant that has leaked to the water flow passage, to flow out from the water flow passage through the pressure relief valve 30.

[0048] Furthermore, the pressure relief valve 30 is located in the outdoor space. Therefore, when flowing out of the pressure relief valve 30, the refrigerant flows out to the outdoor space without flowing into the indoor space where the heating terminal 23, the indoor unit 52, and other devices are installed. It is therefore possible to reduce the possibility that suffocation will be caused by the refrigerant gas in the indoor space. Furthermore, in the case where the refrigerant is combustible, it is possible to reduce the possibility that the refrigerant gas will burn in the indoor space because the refrigerant does not flow into the indoor space. Thus, the safety in the indoor space can be improved.

[0049] Regarding Embodiment 1, although it is described above that the connection port 48 is provided continuous with the second through-holes 42B of the heat transfer plates 41 and opposite to the first outlet port 45; it is not limiting. The connection port 48 may be provided continuous with the first through-holes 42A and opposite to the first inlet port 44. Furthermore, the end plate 43A includes the second inlet port 46, the second outlet port 47, and the connection port 48, and the end plate 43B includes the first inlet port 44 and the first outlet port 45; however, the arrangement of these inlet and outlet ports is not limited to the above arrangement. For example, the end plate 43A may include only the connection port 48, and the end plate 43B may include the first inlet port 44, the first outlet port 45, the second inlet port 46, and the second outlet port 47.

[0050] Furthermore, the plate heat exchanger 40 is housed in the outdoor unit 51 and is located in the outdoor space; however, the position of the plate heat exchanger 40 is not limited to the above position. The plate heat

exchanger 40 may be provided solely in the outdoor space without being housed in the outdoor unit 51. Alternatively, the plate heat exchanger 40 may be provided in the indoor space. In this case, the pressure relief valve 30 connected to the plate heat exchanger 40 may not be located in the outdoor space, and it suffices that a pipe that allows the fluid such as the refrigerant to flow out from the pressure relief valve 30 to the outdoor space is connected to the pressure relief valve 30.

[0051] Furthermore, although it is described above that the water is used as the heat medium that circulates in the heat medium circuit, it is not limiting. The heat medium may be, for example, an antifreeze solution such as ethylene glycol, or water mixed with the antifreeze solution. Furthermore, although it is described above that the heating terminal 23 is used as the use-side heat exchanger connected to the heat medium circuit, it is not limiting. The use-side heat exchanger may be, for example, a hot water storage tank that internally includes a heat exchange unit to generate hot water and accumulates the hot water.

[0052] Furthermore, the safety valve 25 is provided in the water circuit 20; however, the safety valve 25 may not be provided in the water circuit 20. In this case, since the pressure relief valve 30 is connected to the water circuit 20 as illustrated in Fig. 1, the pressure relief valve 30 can also fulfill the function of the safety valve 25. In other words, for example, even in the case where the pressure in the water circuit 20 is abnormally raised by a cause other than leakage of the refrigerant in the plate heat exchanger 40, the pressure relief valve 30 is opened to cause the water in the water circuit 20 to flow out to the outside, to thereby protect components, devices, etc., in the water circuit 20 against a water pressure. In the case where the safety valve 25 is provided in the water circuit 20, the water circuit 20 is protected against the water pressure, by both the pressure relief valve 30 and the safety valve 25. It is therefore possible to improve the reliability of the water circuit 20 with respect to protection of the water circuit 20 against the water pressure. For example, even if a failure occurs at one of the pressure relief valve 30 and the safety valve 25, the water circuit 20 can be protected by the other of the pressure relief valve 30 and the safety valve 25. Furthermore, in this case, for example, the set value of the safety valve 25 may be made slightly higher than the set value of the pressure relief valve 30, whereby not the safety valve 25 but the pressure relief valve 30 is more reliably opened, when the refrigerant leaks and the pressure rises in the plate heat exchanger 40.

(Embodiment 2)

[0053] Next, a heat pump apparatus 2 according to Embodiment 2 of the present disclosure will be described with reference to Fig. 7. Fig. 7 is a schematic diagram illustrating a configuration of the heat pump apparatus 2. Regarding Embodiment 2, components that have the

same configurations as those of the above heat pump apparatus 1 according to Embodiment 1 will be denoted by the same reference signs, and their detailed descriptions will be omitted.

[0054] In the heat pump apparatus 2 according to Embodiment 2, a check valve 26 is provided in the water circuit 20. In this regard, the heat pump apparatus according to Embodiment 2 is different from the heat pump apparatus 1 according to Embodiment 1. As illustrated in Fig. 7, the check valve 26 is provided between the pump 22 and the plate heat exchanger 40 in the water circuit 20. The check valve 26 maintains at all times the flow direction of the water in the water circuit that flows in a direction from the pump 22 toward the plate heat exchanger 40, thereby preventing the water from flowing backward. Furthermore, in Embodiment 2, the check valve 26 is housed in the indoor unit 52.

[0055] In the plate heat exchanger 40, if the heat transfer plates 41 are damaged, and the water flow passage and the refrigerant flow passage communicate with each other, the refrigerant flows into the water flow passage, and the pressure in the water flow passage is raised. Consequently, a pressure is applied to the check valve 26 of the water circuit 20 in a back-flow direction. At this time, the check valve 26 is closed to prevent the water in the water circuit 20 from flowing in the back-flow direction, and stops the flow of the water. Therefore, the refrigerant that has flowed into the water flow passage does not easily flow from the first inlet port 44 to the water circuit 20. It is therefore possible to cause the refrigerant that has flowed into the water flow passage to flow out more concentratedly from the pressure relief valve 30.

[0056] Also, in the heat pump apparatus 2 having such a configuration, it is possible to obtain advantages similar to the advantages obtained by the heat pump apparatus 1 according to Embodiment 1.

(Embodiment 3)

[0057] Next, the heat pump apparatus 1 according to Embodiment 3 of the present disclosure will be described with reference to Fig. 8. Fig. 8 is a sectional view taken along line IV-IV in Fig. 3 in a state where the pressure relief valve is attached. Regarding Embodiment 3, the connection between the pressure relief valve 30 and the plate heat exchanger 40 of the heat pump apparatus 1 as described in Embodiment 1 will be described in more detail. Therefore, regarding Embodiment 3, components that have the same configurations as those in the above heat pump apparatus 1 according to Embodiment 1 will be denoted by the same reference signs, and their detailed descriptions will be omitted.

[0058] The pressure relief valve 30 includes a first opening port 30a, a second opening port 30b, an internal valve flow-passage portion 30c, and a valve body 30d. The first opening port 30a is connected to the connection port 48 of the plate heat exchanger 40. The second opening port 30b serves as an outlet port through which the

refrigerant or the water in the water circuit 20 flows out in the case where the pressure relief valve 30 is opened. In the case where an outflow pipe is connected to the pressure relief valve 30, the outflow pipe is connected to the second opening port 30b. The internal valve flow-passage portion 30c forms a flow passage that causes the first opening port 30a and the second opening port 30b to communicate with each other. The valve body 30d is provided in an intermediate portion of the internal valve flow-passage portion 30c. In the case where the pressure in the water circuit 20 is lower than or equal to a predetermined set value, the valve body 30d closes the flow passage formed by the internal valve flow-passage portion 30c. In other words, in the case where the pressure in the water circuit 20 is lower than or equal to the set value, the pressure relief valve 30 is closed, the second opening port 30b and the water circuit 20 do not communicate with each other, and the refrigerant or the water in the water circuit 20 does not flow out from the second opening port 30b. In the case where the pressure in the water circuit 20 exceeds the set value, the valve body 30d opens the flow passage formed by the internal valve flow-passage portion 30c. In other words, in the case where the pressure in the water circuit 20 exceeds the set value, the pressure relief valve 30 is in the opened state, the second opening port 30b and the water circuit 20 communicate with each other, and the water or the refrigerant in the water circuit 20 flows out from the second opening port 30b. Furthermore, when the pressure in the water circuit 20 exceeds the set value and the valve body 30d is opened, and then when the pressure in the water circuit 20 is reduced lower than or equal to the set value, the state of the valve body 30d is returned to a closed state in which the valve body 30d closes the flow passage formed by the internal valve flow-passage portion 30c.

[0059] The connection port 48 is provided to extend from the end plate 43A toward the outside of the plate heat exchanger 40. Furthermore, the first opening port 30a of the pressure relief valve 30 is connected to a front end of the connection port 48. In other words, the connection port 48 is connected to the pressure relief valve 30 provided separately from the plate heat exchanger 40. Moreover, the entire pressure relief valve 30 is located further outward of the plate heat exchanger 40 than the end plate 43A.

[0060] In the plate heat exchanger 40 according to Embodiment 3, the plurality of heat transfer plates 41 and the pair of end plates 43 are provided. The plurality of heat transfer plates 41 are stacked together in a single direction, isolate the first flow passage that allows the first fluid (heat medium) to flow and the second flow passage that allows the second fluid (refrigerant) to flow, and cause heat exchange to be performed between the first fluid in the first flow passage and the second fluid in the second flow passage. In each of the heat transfer plates 41, the first through-hole 42A, the second through-hole 42B, the third through-hole 42C, and the fourth through-

hole 42D are formed to extend through the heat transfer plate 41 in the stacking direction. In the pair of end plates 43A and 43B, the first inlet port 44, the first outlet port 45, the second inlet port 46, the second outlet port 47, and the connection port 48 are provided, and the pair of end plates 43A and 43B are located such that the heat transfer plates 41 are sandwiched between the end plates 43A and 43B in the above single direction. The first inlet port 44 is continuous with the first through-holes 42A and located as a port through which the first fluid flows into the first flow passage. The first outlet port 45 is continuous with the second through-holes 42B and located as a port through which the first fluid flows out from the first flow passage. The second inlet port 46 is continuous with the third through-holes 42C and located as a port through which the second fluid flows into the second flow passage. The second outlet port 47 is continuous with the fourth through-holes 42D and located as a port through which the second fluid flows out from the second flow passage. The connection port 48 is continuous with the first through-holes 42A or the second through-holes 42B, branches off from the first flow passage, and is connected to the pressure relief valve 30 provided separately from the plate heat exchanger 40. In this configuration, since the pressure relief valve 30 is provided separately from the plate heat exchanger 40, the pressure relief valve 30 can be more flexibly designed. For example, unlike the configuration of Embodiment 3, in the case where a pressure relief valve employing a rubber plug that is elastically deformed to fit into the connection port or an aluminum tape pasted to the connection port is combined with a plate heat exchanger into a single body, it is hard to adjust the set pressure. However, in a configuration in which the pressure relief valve 30 is provided separately from the plate heat exchanger 40, a valve configured such that the set pressure can be adjusted can be used as the pressure relief valve 30.

[0061] Furthermore, the heat pump apparatus 1 according to Embodiment 3 includes: the refrigerant circuit 10 in which the compressor 12, the plate heat exchanger 40, the expansion mechanism 13, and the heat-source-side heat exchanger are connected by the refrigerant pipes 11 to circulate the refrigerant; the heat medium circuit in which the pump 22, the plate heat exchanger 40, and the use-side heat exchanger are connected by the heat medium pipes to circulate the heat medium; and the pressure relief valve 30 that is connected to the connection port 48 branching off from the heat medium circuit in the plate heat exchanger 40, and that is provided separately from the plate heat exchanger 40. In this configuration, since the pressure relief valve 30 is provided separately from the plate heat exchanger 40, as the pressure relief valve 30, an appropriate valve can be selected from a larger number of kinds of valves, and the pressure

relief valve 30 can be more flexibly designed.

[0062] Furthermore, in the heat pump apparatus 1 according to Embodiment 3, as an additional configuration, the plate heat exchanger 40 include the plurality of heat transfer plates 41 and the pair of end plates 43. The heat transfer plates 41 are stacked together in the single direction, isolate the first flow passage (heat medium circuit) through which the first fluid (heat medium) flows and the second flow passage (refrigerant circuit) through which the second fluid (refrigerant) flows, and cause heat exchange to be performed between the first fluid in the first flow passage and the second fluid in the second flow passage. Each of the heat transfer plates 41 includes the first through-hole 42A, the second through-hole 42B, the third through-hole 42C, and the fourth through-hole 42D that extend through the heat transfer plate 41 in the single direction. The end plates 43 include the first inlet port 44, the first outlet port 45, the second inlet port 46, the second outlet port 47, and the connection port 48, and are located such that the heat transfer plates 41 are sandwiched between the end plates 43. The first inlet port 44 is continuous with the first through-holes 42A and located as a port through which the first fluid flows into the first flow passage. The first outlet port 45 is continuous with the second through-holes 42B and located as a port through which the first fluid flows from the first flow passage. The second inlet port 46 is continuous with the third through-holes 42C and located as a port through which the second fluid flows into the second flow passage. The second outlet port 47 is continuous with the fourth through-holes 42D and located as a port through which the second fluid flows out from the second flow passage. The connection port 48 is continuous with the first through-holes 42A or the second through-holes 42B and being branched from the first flow passage. Because of the additional configuration, the heat pump apparatus according to Embodiment 3 can prevent the water from being cooled by the refrigerant, and thus prevent ice from being made, that is, can prevent the pressure relief valve from being closed by ice, as described in Embodiment 1. It is therefore possible to more reliably cause the refrigerant that has leaked to the water flow passage, to flow out from the water flow passage through the pressure relief valve 30.

[0063] Furthermore, the heat pump apparatus 1 according to Embodiment 3 has as another additional configuration the following configuration: in the case where the pressure in the heat medium circuit exceeds the predetermined set value, the pressure relief valve 30 is opened, and in the case where the pressure in the heat medium circuit is less than or equal to the set value after the pressure relief valve 30 is opened, the pressure relief valve 30 is closed. Because of provision of this additional configuration, the heat pump apparatus according to Embodiment 3 can reduce the outflow amount of the heat medium or refrigerant. In particular, this is more advantageous in the case where the refrigerant is combustible. That is, since the outflow amount of the refrigerant can be reduced, it is possible to reduce the probability with

which the density of staying refrigerant reaches a density at which the refrigerant burns, by reducing the outflow amount of the refrigerant.

[0064] Furthermore, the heat pump apparatus 1 according to Embodiment 3 has as a further additional configuration the following configuration: in which the entire pressure relief valve 30 is located outside the plate heat exchanger 40. If part of the pressure relief valve is located in the plate heat exchanger, the pressure relief valve may block the flow of the fluid that flows through the heat transfer plates, thus reducing the heat exchange efficiency of the plate heat exchanger. By contrast, in the heat pump apparatus according to Embodiment 3, because of the above additional configuration, the pressure relief valve does not block the flow of the fluid that flows through the heat transfer plates, and the heat exchange efficiency is not reduced.

[0065] The heat pump apparatus 1 according to Embodiment 3 has as still another configuration the following configuration: the pressure relief valve 30 is provided in the outdoor space. Because of this configuration, the heat pump apparatus 1 according to Embodiment 3 can reduce the possibility with which in the indoor space, suffocation may be caused by the refrigerant gas as described in Embodiment 1. In particular, this is more advantageous in the case where the refrigerant is combustible. That is, since the refrigerant does not flow into the indoor space, it is possible to reduce the possibility that the refrigerant gas will burn in the indoor space.

[0066] The heat pump apparatus 1 according to Embodiment 3 has as a still further additional configuration the following configuration: the outflow pipe through which the fluid that has flowed out from the pressure relief valve 30 flows out to the outdoor space is connected to the pressure relief valve 30. Because of this additional configuration, the heat pump apparatus 1 according to Embodiment 3 can reduce the possibility with which suffocation may be caused by the refrigerant gas in the indoor space, as described in Embodiment 1. In particular, this is more advantageous in the case where the refrigerant is combustible. That is, since the refrigerant does not flow to the indoor space, it is possible to reduce the possibility with which refrigerant gas may burn in the indoor space.

[0067] A modification of Embodiment 3 will be described.

[0068] The check valve 26 as described regarding Embodiment 2 may be provided in the heat pump apparatus 1 according to Embodiment 3. To be more specific, a heat pump apparatus of the modification of Embodiment 3 has as an additional configuration the following configuration: in the heat medium circuit, the check valve is provided between the pump and the plate heat exchanger. Because of this additional configuration, in the heat pump apparatus of the modification of Embodiment 3, it is possible to cause the refrigerant that has flowed into the heat medium flow passage to flow out more concentratedly from the pressure relief valve, as described re-

garding Embodiment 2.

[0069] In the heat pump apparatus 1 according to Embodiment 3, it is preferably that a flow-passage sectional area of the first opening port 30a, a flow-passage sectional area of the second opening port 30b, and a flow-passage sectional area of the flow passage formed by the internal valve flow-passage portion 30c be each greater than a flow-passage sectional area of the connection port 48. The flow-passage sectional area means a sectional area at a surface perpendicular to the flow direction of the water or the refrigerant that flows through the flow passage. The flow direction of the water or the refrigerant that flows through the first opening port 30a, the second opening port 30b, and the flow passage formed by the internal valve flow-passage portion 30c is the flow direction of the water or the refrigerant that flows out from the second opening port 30b, with the pressure relief valve 30 opened. That is, the heat pump apparatus according to the modification of Embodiment 3 has as an additional configuration the following configuration: the pressure relief valve includes the first opening port connected to the connection port, the second opening port through which the heat medium or the refrigerant flows out, and the internal valve flow-passage portion forming the flow passage through which the first opening port and the second opening port communicate with each other; and the flow-passage sectional area of the first opening port, the flow-passage sectional area of the second opening port, and the flow-passage sectional area of the flow passage formed by the internal valve flow-passage portion are each greater than the flow-passage sectional area of the connection port. Because of this additional configuration, even when ice adheres to the flow passage in the pressure relief valve, the pressure relief valve is not easily closed.

[0070] In the heat pump apparatus 1 according to Embodiment 3, the connection port 48 and the pressure relief valve 30 are directly connected to each other; however, the connection between the connection port and the pressure relief valve is not limited to such a direct connection. For example, the connection port and the pressure relief valve may be connected by a connection pipe. That is, the heat pump apparatus of the modification of Embodiment 3 has as another additional configuration the following configuration: the connection port and the pressure relief valve are connected by the connection pipe. Because of this additional configuration, in the heat pump apparatus of the modification of Embodiment 3, the location of the pressure relief valve is further flexible. In particular, this is more advantageous in the case where the refrigerant is combustible. That is, the pressure relief valve can be provided far from a component that can become an ignition source, such as an electric circuit. It is therefore possible to reduce the possibility that the refrigerant may burn.

[0071] Furthermore, preferably, the flow-passage sectional area of the connection pipe should be greater than the flow-passage sectional area of the connection port

48. That is, the heat pump apparatus of the modification of Embodiment 3 has as a further additional configuration the following configuration: the flow-passage sectional area of the connection pipe is greater than the flow-passage sectional area of the connection port. Because of this additional configuration, even if ice adheres to the flow passage in the pressure relief valve, the pressure relief valve is not easily closed.

[0072] In the heat pump apparatus 1 according to Embodiment 3, the flow-passage sectional area of the connection port 48 and the flow-passage sectional area of the first outlet port 45 are substantially equal to each other; however, the relationship between the flow-passage sectional areas of the connection port 48 and the first outlet port 45 is not limited to the above relationship. The flow-passage sectional area of the connection port may be made greater than the flow-passage sectional area of the first outlet port. That is, the plate heat exchanger or the heat pump apparatus of the modification of Embodiment 3 has as still another additional configuration the following configuration: the flow-passage sectional area of the connection port is greater than the flow-passage sectional area of the first outlet port. In general, the refrigerant easily flows out from an outflow port having a large flow-passage sectional area. In other words, in the case where the flow-passage sectional area of the connection port is greater than the flow-passage sectional area of the first outlet port, the refrigerant that has leaked to the heat medium circuit easily flows out to the connection port having a large flow-passage sectional area than the first outlet port having a small flow-passage sectional area. Therefore, because of this additional configuration, in the plate heat exchanger or the heat pump apparatus of the modification of Embodiment 3, when the refrigerant leaks to the heat medium circuit, this leak refrigerant easily flows out to the connection port 48, and can be made to promptly flow out to the outside.

(Embodiment 4)

[0073] Next, a heat pump apparatus 3 according to Embodiment 4 of the present disclosure will be described with reference to Figs. 9 and 10. Fig. 9 is a schematic front view illustrating a plate heat exchanger according to Embodiment 4 of the present disclosure. Fig. 10 is a sectional view taken along line X-X in Fig. 9. It should be noted that components that have the same configurations as those in the above heat pump apparatus 1 according to Embodiment 1 will be denoted by the same reference signs, and their detailed descriptions will thus be omitted.

[0074] In the heat pump apparatus 3 according to Embodiment 4, a temperature sensor 31 is attached to the plate heat exchanger 40. In this regard, the heat pump apparatus according to Embodiment 4 is different from the heat pump apparatus 1 according to Embodiment 1. As the temperature sensor 31, for example, a thermistor is used.

[0075] The temperature sensor 31 is provided on a surface of the end plate 43A. As described regarding Embodiment 1, the end plate 43A includes the connection port 48 connected to the pressure relief valve 30, the second inlet port 46, and the second outlet port 47. Furthermore, the temperature sensor 31 is provided close to the connection port 48. Therefore, the distance between the temperature sensor 31 and the connection port 48 is smaller than the distance between the temperature sensor 31 and the second inlet port 46 and the distance between the temperature sensor 31 and the second outlet port 47. In the case where the first inlet port 44 or the first outlet port 45 is provided in the end plate 43A, the distance between the temperature sensor 31 and the connection port 48 is smaller than the distance between the temperature sensor 31 and the first inlet port 44 and the distance between the temperature sensor 31 and the first outlet port 45.

[0076] Furthermore, as viewed from a direction perpendicular to the surface of the end plate 43A, the temperature sensor 31 is located between the connection port 48 and an end portion 43A1 of the end plate 43A. In addition, the second inlet port 46 and the second outlet port 47 are not located between the connection port 48 and the end portion 43A1 of the end plate 43A. That is, the temperature sensor 31 is located between the connection port 48 and the end portion 43A1 of the end plate 43A, and the other inlet port and outlet port provided in the end plate 43A are not located between the connection port 48 and the end portion 43A1 of the end plate 43A.

[0077] The temperature sensor 31 detects the temperature of the surface of the end plate 43A. The temperature of the surface of the end plate 43A follows the temperature of the water that flows in the plate heat exchanger 40, that is, as the temperature of the water that flows in the plate heat exchanger 40 rises or drops, the temperature of the surface of the end plate 43A also rises or drops. Therefore, the temperature sensor 31 detects a temperature related to the water that flows in the plate heat exchanger 40.

[0078] The temperature sensor 31 is connected to a controller not illustrated such that the temperature sensor 31 can communicate with the controller. Information on the temperature detected by the temperature sensor 31 is transmitted to the controller. The controller is connected to at least the compressor 12 such that the controller can communicate with the compressor 12. The controller can control the compressor 12 based on the received information on the temperature detected by the temperature sensor 31. In the case where the temperature detected by the temperature sensor 31 that is indicated by the received information is less than a predetermined threshold, the controller stops an operation of the compressor 12. Furthermore, the controller finally stops the pump, the fan, and the other components included in the heat pump apparatus. Also, it is preferable that the controller include a notification unit that notifies a user of detection of refrigerant leakage. It should be noted that

the controller includes a processor that executes a control program, a memory that stores the control program to be executed by the processor, and a hardware interface that connects the processor or the memory to the temperature sensor 31 and the compressor 12 such that the processor or the memory can communicate with the temperature sensor 31 and the compressor 12.

[0079] The plate heat exchanger 40 according to Embodiment 4 includes the plurality of the heat transfer plates 41 and the pair of end plates 43. Each of the heat transfer plates 41 includes the first through-hole 42A, the second through-hole 42B, the third through-hole 42C, and the fourth through-hole 42D that extend through the heat transfer plate 41 in the single direction. The heat transfer plates 41 are stacked together in the single direction, isolate the first flow passage (heat medium circuit) through which the first fluid (heat medium) flows and the second flow passage (refrigerant circuit) through which the second fluid (refrigerant) flows, and cause heat exchange to be performed between the first fluid in the first flow passage and the second fluid in the second flow passage. The pair of end plates 43A and 43B include the first inlet port 44, the first outlet port 45, the second inlet port 46, the second outlet port 47, and the connection port 48, and are located such that the heat transfer plates 41 are sandwiched between the end plates 43 in the single direction. The first inlet port 44 is continuous with the first through-holes 42A and located as a port through which the first fluid flows into the first flow passage. The first outlet port 45 is continuous with the second through-holes 42B and located as a port through which the first fluid flows out from the first flow passage. The second inlet port 46 is continuous with the third through-holes 42C and located as a port through which the second fluid flows into the second flow passage. The second outlet port 47 is continuous with the fourth through-holes 42D and located as a port through which the second fluid flows out from the second flow passage. The connection port 48 is continuous with the first through-holes 42A or the second through-holes 42B, branches off from the first flow passage, and is a port for connection of the pressure relief valve 30. Because of the above configuration, the plate heat exchanger 40 according to Embodiment 4 can prevent the water from being cooled by the refrigerant, and thus prevent ice from being made, thereby preventing the pressure relief valve from being closed by ice, as described in Embodiment 1.

[0080] Furthermore, the plate heat exchanger 40 according to Embodiment 4 includes as an additional configuration a temperature sensor that detects a temperature related to the heat medium that flows in the plate heat exchanger 40. Because of this additional configuration, in the plate heat exchanger 40 according to Embodiment 4, the temperature sensor 31 can detect the temperature related to the refrigerant that flows in the plate heat exchanger 40. If the plate heat exchanger 40 is damaged and a refrigerant leak occurs, this leak refrigerant is made to flow out from the pressure relief valve

30 attached to the plate heat exchanger 40 to the outside. Therefore, in the entire flow passage in the water circuit 20 in the heat pump apparatus 1, the temperature of the water flow passage in the plate heat exchanger 40 drops first. Therefore, because of the additional configuration, when a refrigerant leak occurs, the plate heat exchanger 40 according to Embodiment 4 can early detect the refrigerant leak.

[0081] The plate heat exchanger 40 according to Embodiment 4 has as another additional configuration the following configuration: the temperature sensor 31 is attached to the end plate 43A having the connection port 48. In the case where a refrigerant leakage occurs, this leak refrigerant is made to flow out from the pressure relief valve 30 connected to the connection port 48 to the outside. Therefore, because of this additional configuration, since the temperature of the end plate 43A including the connection port 48 remarkably drops as compared with the temperature of the other end plate 43B, the plate heat exchanger 40 according to Embodiment 4 can more reliably detect the refrigerant leak.

[0082] The plate heat exchanger 40 according to Embodiment 4 has as a further additional configuration the following configuration: in the end plate 43A having the connection port 48, at least one of the first inlet port 44, the first outlet port 45, the second inlet port 46, and the second outlet port 47 is provided, and the distance between the connection port 48 and the temperature sensor 31 is smaller than a distance between the temperature sensor 31 and each of the first inlet port 44, the first outlet port 45, the second inlet port 46, and the second outlet port 47 in the end plate 43A having the connection port 48. Because of this additional configuration, the temperature detected by the temperature sensor 31 is not easily influenced by the temperature of the fluid that flows through the other inlet port or outlet port, and is greatly influenced by the temperature of the fluid located close to the connection port 48 that is reduced by the refrigerant leak. Therefore, the plate heat exchanger 40 according to Embodiment 4 can more reliably detect the refrigerant leak.

[0083] Furthermore, the plate heat exchanger 40 according to Embodiment 4 has as still another configuration the following configuration: as viewed from a direction perpendicular to the surface of the end plate 43A having the connection port 48, the temperature sensor 31 is located between the connection port 48 and the end portion 43A1 of the end plate 43A, and none of the first inlet port 44, the first outlet port 45, the second inlet port 46, and the second outlet port 47 is located between the connection port 48 and the end portion 43A1 of the end plate 43A. Because of this additional configuration, the temperature detected by the temperature sensor 31 is not easily influenced by the temperature of the fluid that flows through the other inlet port or outlet port, and is greatly influenced by the temperature of the fluid located close to the connection port 48 that is reduced by a refrigerant leak. Therefore, the plate heat exchanger 40

according to Embodiment 4 can more reliably detect the refrigerant leak.

[0084] Furthermore, the additional configurations of the plate heat exchanger 40 according to Embodiment 4 may be combined with the heat pump apparatus 1 having the following configuration. The heat pump apparatus 1 includes: the refrigerant circuit 10 in which the compressor 12, the plate heat exchanger 40, the expansion mechanism 13, and the heat-source-side heat exchanger are connected by the refrigerant pipes 11 to circulate the refrigerant; the heat medium circuit in which the pump 22, the plate heat exchanger 40, and the use-side heat exchanger are connected by the heat medium pipes to circulate the heat medium; and the pressure relief valve 30 connected to the connection port 48 that branches off from the heat medium circuit in the plate heat exchanger 40.

[0085] The heat pump apparatus 1 according to Embodiment 4 includes as a still further additional configuration the controller that is connected to the temperature sensor 31 and the compressor 12 such that the controller can communicate with the temperature sensor 31 and the compressor 12, and when the temperature detected by the temperature sensor 31 is less than a predetermined threshold, the controller stops the compressor 12. Because of this additional configuration, when a refrigerant leak occurs, the compressor can be automatically stopped, and it is possible to reduce the influence of the refrigerant leak. Furthermore, the following additional configurations are provided: firstly, the controller finally stops the pump, the fan, and the other components that are included in the heat pump apparatus, and because of this additional configuration, the heat pump apparatus can be automatically stopped when a refrigerant leak occurs, and the influence of the refrigerant leak can be reduced; and secondly, preferably, the controller should include the notification unit that notifies the user of detection of the refrigerant leak, and because of the above additional configuration, it is possible to notify the user of occurrence of the refrigerant leak.

[0086] A modification of Embodiment 4 will be described.

[0087] Any of the additional configurations described in Embodiment 4 may be added to the heat pump apparatus 1 according to Embodiment 3. Any of the additional configurations described in Embodiment 4 may be added to the plate heat exchanger 40 having the following configuration or the heat pump apparatus 1 having the following configuration. The plate heat exchanger 40 according to Embodiment 4 includes the plurality of the heat transfer plates 41 and the pair of end plates 43. Each of the heat transfer plates 41 includes the first through-hole 42A, the second through-hole 42B, the third through-hole 42C, and the fourth through-hole 42D that extend through the heat transfer plate 41 in the single direction. The heat transfer plates 41 are stacked together in the single direction, isolate the first flow passage (heat medium circuit) through which the first fluid (heat medium) flows and

the second flow passage (refrigerant circuit) through which the second fluid (refrigerant) flows, and cause heat exchange to be performed between the first fluid in the first flow passage and the second fluid in the second flow passage. The pair of end plates 43A and 43B include the first inlet port 44, the first outlet port 45, the second inlet port 46, the second outlet port 47, and the connection port 48, and are located such that the heat transfer plates 41 are sandwiched between the end plates 43 in the single direction. The first inlet port 44 is continuous with the first through-holes 42A and located as a port through which the first fluid flows into the first flow passage. The first outlet port 45 is continuous with the second through-holes 42B and located as a port through which the first fluid flows out from the first flow passage. The second inlet port 46 is continuous with the third through-holes 42C and located as a port through which the second fluid flows into the second flow passage. The second outlet port 47 is continuous with the fourth through-holes 42D and located as a port through which the second fluid flows out from the second flow passage. The connection port 48 is continuous with the first through-holes 42A or the second through-holes 42B, branches off from the first flow passage, and is connected to the pressure relief valve 30 provided separately from the plate heat exchanger 40. The heat pump apparatus 1 includes: the refrigerant circuit 10 in which the compressor 12, the plate heat exchanger 40, the expansion mechanism 13, and the heat-source-side heat exchanger are connected by the refrigerant pipes 11 to circulate the refrigerant; the heat medium circuit in which the pump 22, the plate heat exchanger 40, and the use-side heat exchanger are connected by the heat medium pipes to circulate the heat medium; and the pressure relief valve 30 that is connected to the connection port 48 branching off from the heat medium circuit in the plate heat exchanger 40, and that is provided separately from the plate heat exchanger 40.

[0088] Fig. 11 is a sectional view of a plate heat exchanger according to a modification of Embodiment 4 taken along line X-X in Fig. 9. As illustrated in Fig. 11, the temperature sensor 31 may be provided at the heat transfer plate 41 located on a side surface of the plate heat exchanger 40. In other words, the plate heat exchanger of the modification of Embodiment 4 has as an additional configuration the following configuration in which the temperature sensor is attached to the heat transfer plate located on the side surface of the plate heat exchanger. Because of this additional configuration, the plate heat exchanger of the modification of Embodiment 4 can directly detect the temperature of the surface of the heat transfer plate 41; that is, it does not detect the temperature of the surface of the heat transfer plate 41 through the end plate 43A. Therefore, if a refrigerant leak occurs, the refrigerant leak can be detected early. Furthermore, it is preferable that the temperature sensor 31 be provided at one of the stacked heat transfer plates 41 that is located close to the connection port 48. The temperature of the surface of the heat transfer plate 41 can

be directly detected, and the temperatures of the leak refrigerant and the water on an outflow side can be detected. It is therefore possible to earlier detect the refrigerant leak.

[0089] Furthermore, the plate heat exchanger of the modification of Embodiment 4 has as another additional configuration the following configuration: the distance between the connection port 48 and the temperature sensor 31 is smaller than the distance between the first inlet port 44 and the temperature sensor 31, the distance between the first outlet port 45 and the temperature sensor 31, the distance between the second inlet port 46 and the temperature sensor 31, and the distance between the second outlet port 47 and the temperature sensor 31. Because of this additional configuration, the temperature of the fluid that flows through the other inlet port or outlet port does not greatly influence the temperature detected by the temperature sensor 31, whereas the temperature of the fluid located close to the connection port 48 that is reduced by a refrigerant leak greatly influences the temperature detected by the temperature sensor 31. Therefore, the plate heat exchanger 40 of the modification of Embodiment 4 can more reliably detect refrigerant leakage.

[0090] Although the preferred embodiments of the present disclosure are described above, these descriptions are not limiting. Addition of a configuration, omission of any of the configurations, replacement of any of the configuration with another configuration, and another modification or other modifications can be made without departing from the scope of the present disclosure.

[0091] In the above plate heat exchanger and the above heat pump apparatus, it is possible to prevent the pressure relief valve from being closed, and to more reliably cause the second fluid that has leaked to the first flow passage, to flow out from the first flow passage through the pressure relief valve.

Reference Signs List

[0092] 1, 2 heat pump apparatus 10 refrigerant circuit 11 refrigerant pipe 12 compressor 13 expansion valve (expansion mechanism) 14 air heat exchanger (heat-source-side heat exchanger) 15 four-way valve 20 water circuit (heat medium circuit) 21 water pipe (heat medium pipe) 22 pump 23 heating terminal (use-side heat exchanger) 24 expansion tank 25 safety valve 26 check valve 30 pressure relief valve 30a first opening port 30b second opening port 30c internal valve flow-passage portion 30d valve body 31 temperature sensor 40 plate heat exchanger 41 heat transfer plate 42A first through-hole 42B second through-hole 42C third through-hole 42D fourth through-hole 43A, 43B end plate 44 first inlet port 45 first outlet port 46 second inlet port 47 second outlet port 48 connection port 51 outdoor unit 52 indoor unit 60 space A communication portion

Claims

1. A plate heat exchanger comprising:

a plurality of heat transfer plates in each of which a first through-hole, a second through-hole, a third through-hole, and a fourth through-hole are provided to extend through the heat transfer plate in a single direction, the plurality of heat transfer plates being stacked together in the single direction, configured to isolate a first flow passage through which a first fluid flows and a second flow passage through which a second fluid flows, and configured to cause heat exchange to be performed between the first fluid in the first flow passage and the second fluid in the second flow passage;

a pair of end plates in which a first inlet port, a first outlet port, a second inlet port, a second outlet port, and a connection port are provided, the pair of end plates being provided such that the plurality of heat transfer plates are sandwiched between the pair of end plates in the single direction, the first inlet port being continuous with the first through-holes and located as a port through which the first fluid flows into the first flow passage, the first outlet port being continuous with the second through-holes and located as a port through which the first fluid flows out from the first flow passage, the second inlet port being continuous with the third through-holes and located as a port through which the second fluid flows into the second flow passage, the second outlet port being continuous with the fourth through-holes and located as a port through which the second fluid flows out from the second flow passage, the connection port being continuous with the first through-holes or the second through-holes, and branching off from the first flow passage, wherein the connection port is connected to a pressure relief valve provided separately from the plate heat exchanger.

2. The plate heat exchanger of claim 1, further comprising a temperature sensor configured to detect a temperature related to the first fluid that flows in the plate heat exchanger.

3. The plate heat exchanger of claim 2, wherein the temperature sensor is attached to one of the end plates that includes the connection port.

4. The plate heat exchanger of claim 3, wherein in the end plate including the connection port, at least one of the first inlet port, the first outlet port, the second inlet port, and the second outlet port is provided, and

a distance between the connection port and the temperature sensor is smaller than a distance between the temperature sensor and each of the first inlet port, the first outlet port, the second inlet port, and the second outlet port that are provided in the end plate including the connection port.

5. The plate heat exchanger of claim 3 or 4, wherein as viewed from a direction perpendicular to a surface of the end plate including the connection port, the temperature sensor is located between the connection port and an end portion of the end plate, and none of the first inlet port, the first outlet port, the second inlet port, and the second outlet port is provided between the connection port and the end portion of the end plate.

6. The plate heat exchanger of claim 2, wherein the temperature sensor is attached to one of the heat transfer plates that is located at a side surface of the plate heat exchanger.

7. The plate heat exchanger of claim 6, wherein a distance between the connection port and the temperature sensor is smaller than a distance between the first inlet port and the temperature sensor, a distance between the first outlet port and the temperature sensor, a distance between the second inlet port and the temperature sensor, and a distance between the second outlet port and the temperature sensor.

8. The plate heat exchanger of any one of claims 1 to 7, wherein a flow-passage sectional area of the connection port is greater than a flow-passage sectional area of the first outlet port.

9. A heat pump apparatus comprising:

a refrigerant circuit in which a compressor, a plate heat exchanger, an expansion mechanism, and a heat-source-side heat exchanger are connected by refrigerant pipes to circulate refrigerant;

a heat medium circuit in which a pump, the plate heat exchanger, and a use-side heat exchanger are connected by heat medium pipes to circulate a heat medium; and

a pressure relief valve connected to a connection port that branches off from part of the heat medium circuit that is located in the plate heat exchanger, the pressure relief valve being provided separately from the plate heat exchanger.

10. The heat pump apparatus of claim 9, wherein the plate heat exchanger includes:

a plurality of heat transfer plates in each of which a first through-hole, a second through-hole, a

third through-hole, and a fourth through-hole are provided to extend through the heat transfer plate in a single direction, the plurality of heat transfer plates being stacked together in the single direction, configured to isolate a first flow passage through which the heat medium flows and a second flow passage through which the refrigerant flows, and configured to cause heat exchange to be performed between the heat medium in the first flow passage and the refrigerant in the second flow passage; and a pair of end plates in which a first inlet port, a first outlet port, a second inlet port, a second outlet port, and the connection port are provided, the first inlet port being continuous with the first through-holes and located as a port through which the heat medium flows from the heat medium pipe into the first flow passage, the first outlet port being continuous with the second through-holes and located as a port through which the heat medium flows out from the first flow passage to the heat medium pipe, the second inlet port being continuous with the third through-holes and located as a port through which the refrigerant flows from the refrigerant pipe into the second flow passage, the second outlet port being continuous with the fourth through-holes and as a port through which the refrigerant flows out from the second flow passage to the refrigerant pipe, the connection port being located continuous with the first through-holes and opposite to the first inlet port or being located continuous with the second through-holes and opposite to the first outlet port.

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

a temperature sensor configured to detect a temperature related to the heat medium that flows in the plate heat exchanger; and a controller connected to the temperature sensor and the compressor such that the controller is allowed to communicate with the temperature sensor and the compressor, wherein the controller stops the compressor when a temperature detected by the temperature sensor is less than a predetermined threshold.

12. The heat pump apparatus of any one of claims 9 to 11, wherein the pressure relief valve is opened when a pressure in the heat medium circuit exceeds a predetermined set value, and the pressure relief valve is closed when the pressure in the heat medium circuit is less than or equal to the set value after the pressure relief valve is opened.

13. The heat pump apparatus of any one of claims 9 to 12, wherein the pressure relief valve is provided in an outdoor space.

14. The heat pump apparatus of any one of claims 9 to 12, wherein an outflow pipe configured to allow a fluid that flows out from the pressure relief valve to flow out to an outdoor space is connected to the pressure relief valve.

15. The heat pump apparatus of any one of claims 9 to 14, wherein in the heat medium, a check valve is provided between the pump and the plate heat exchanger.

FIG. 1

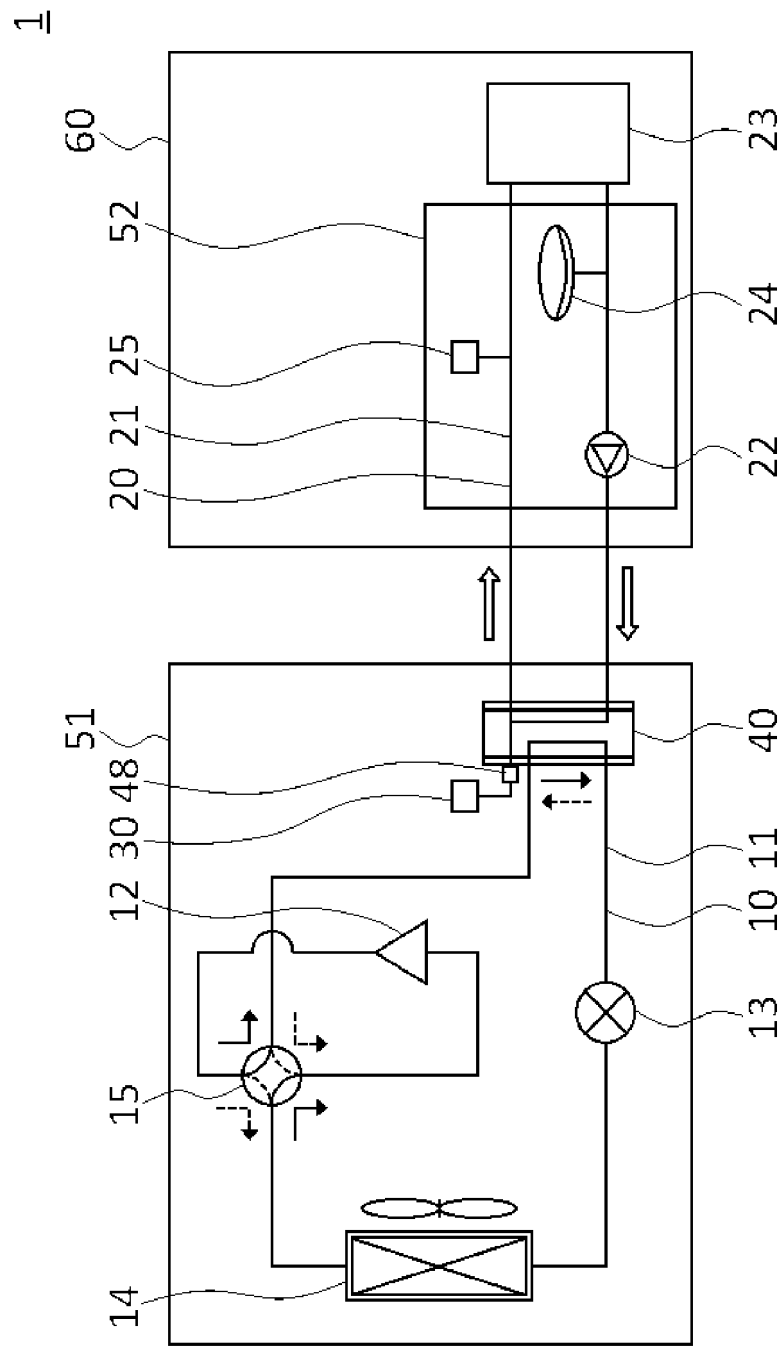


FIG. 2

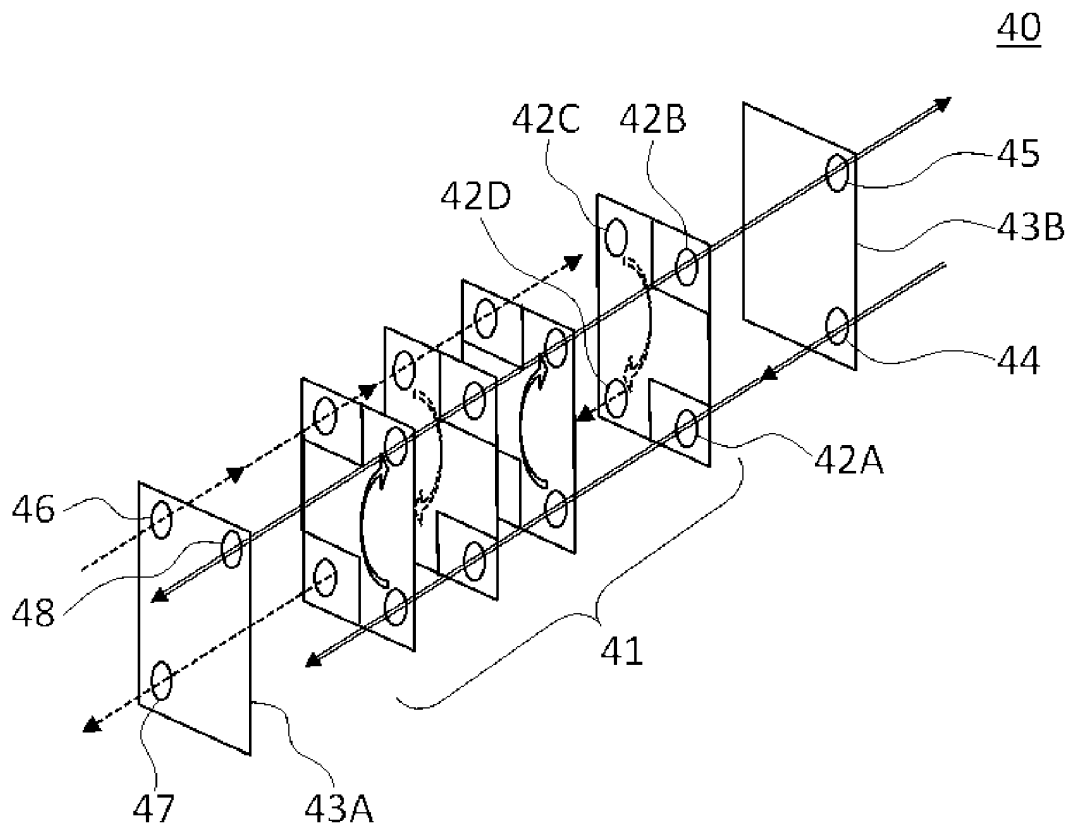


FIG. 3

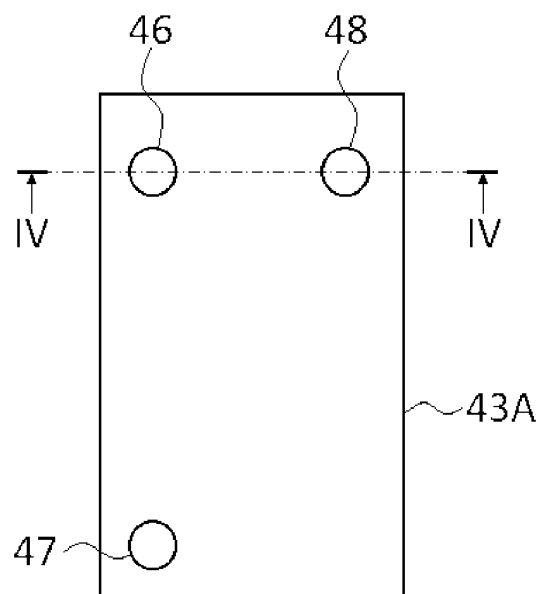


FIG. 4

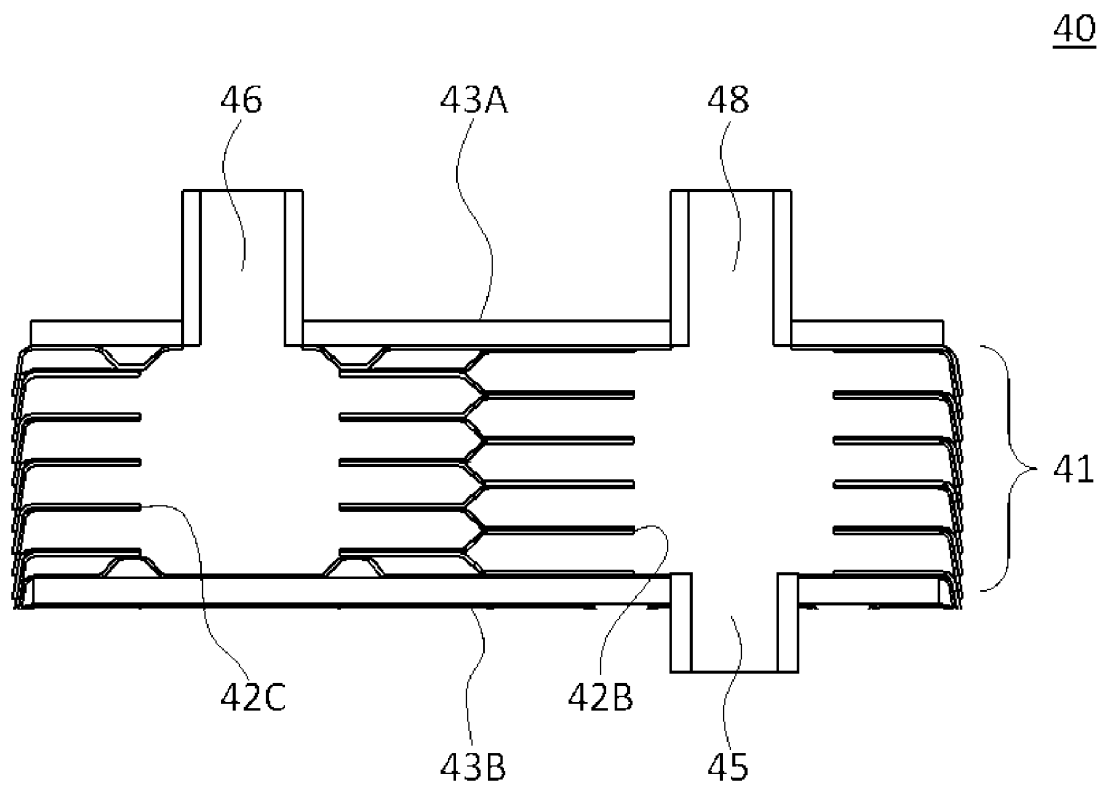


FIG. 5

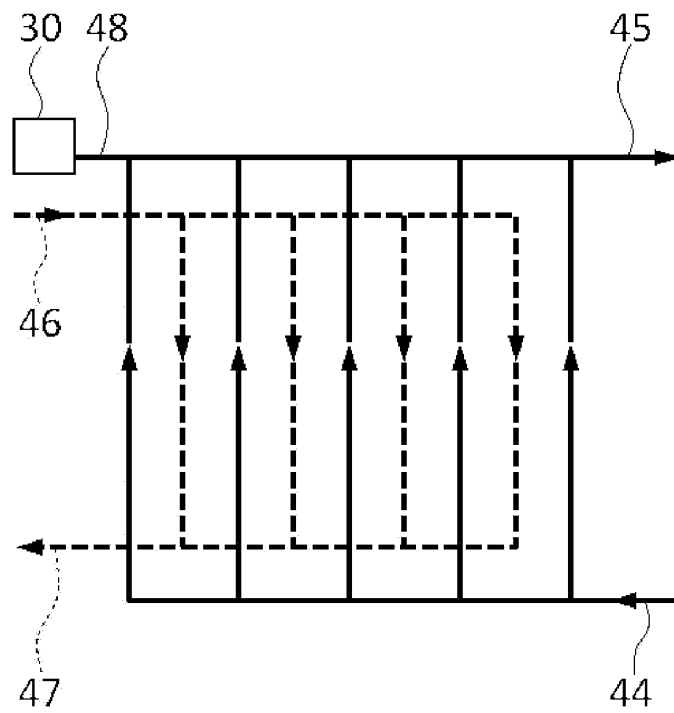


FIG. 6

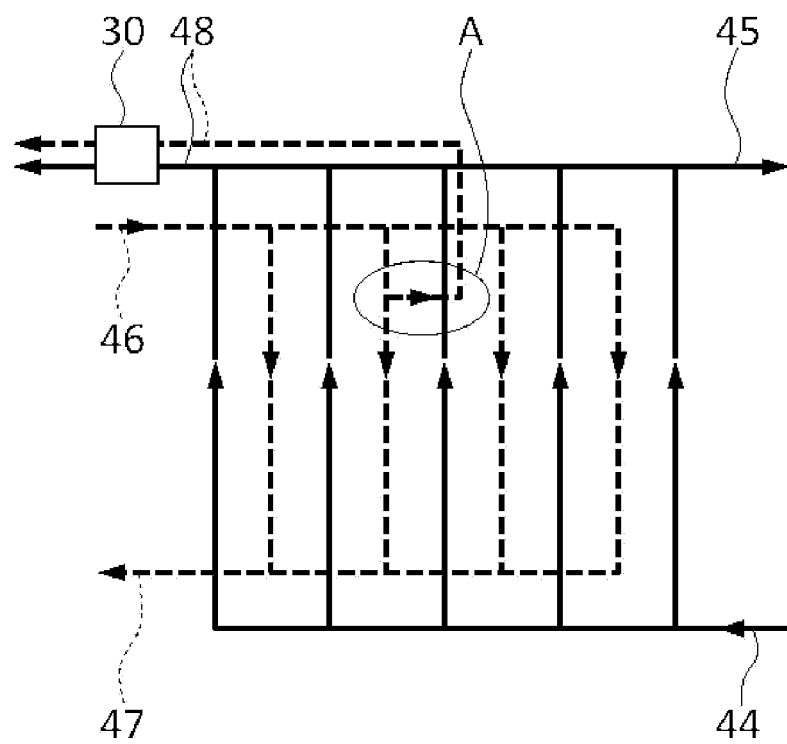


FIG. 7

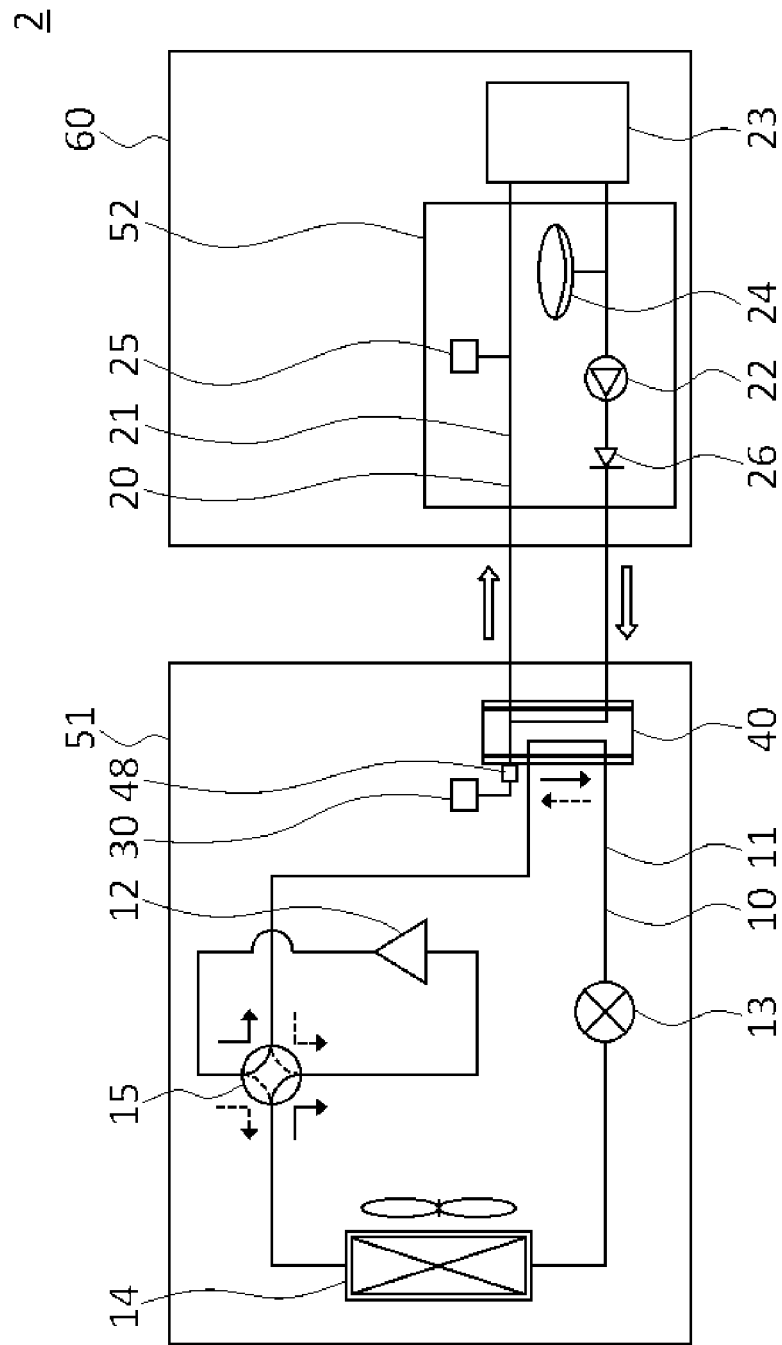


FIG. 8

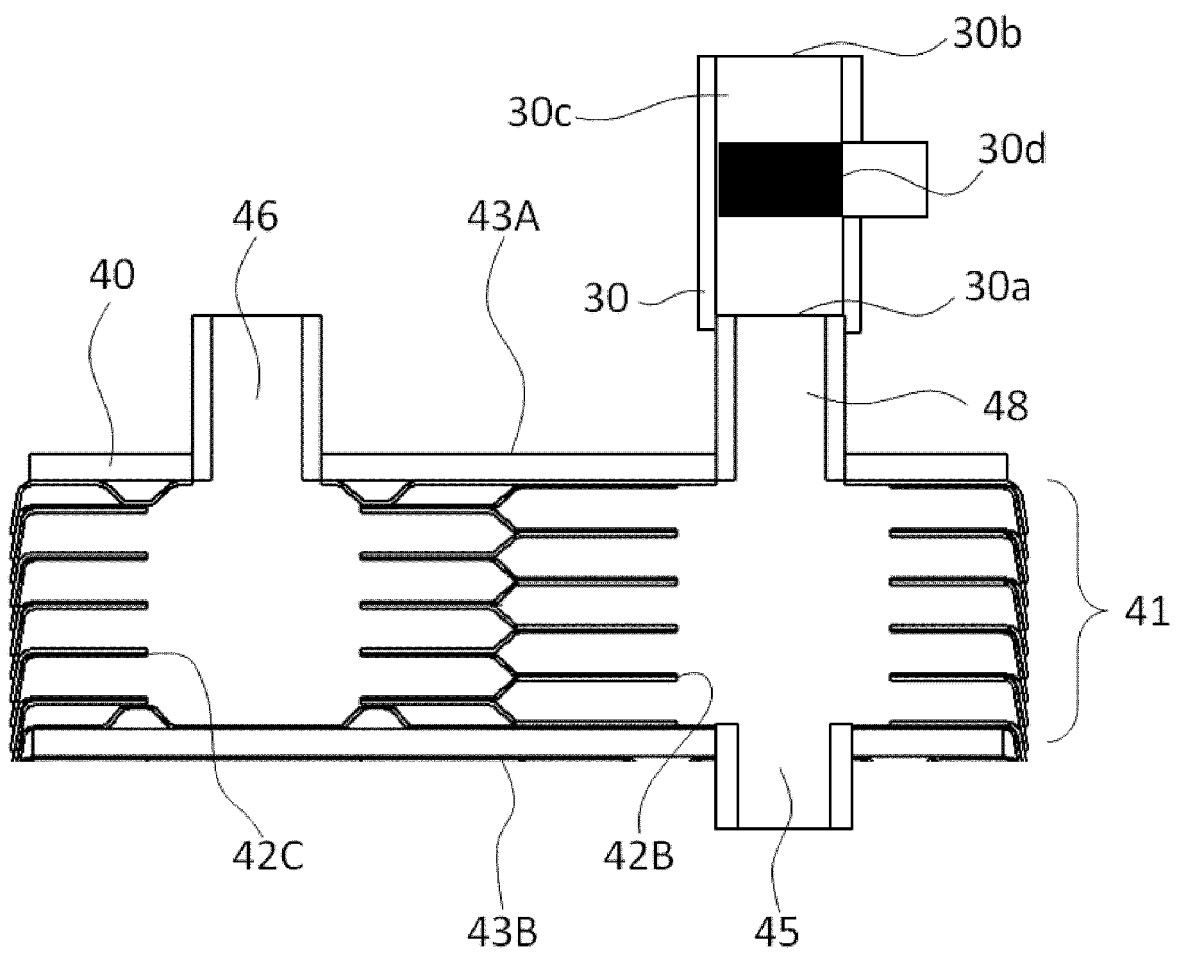


FIG. 9

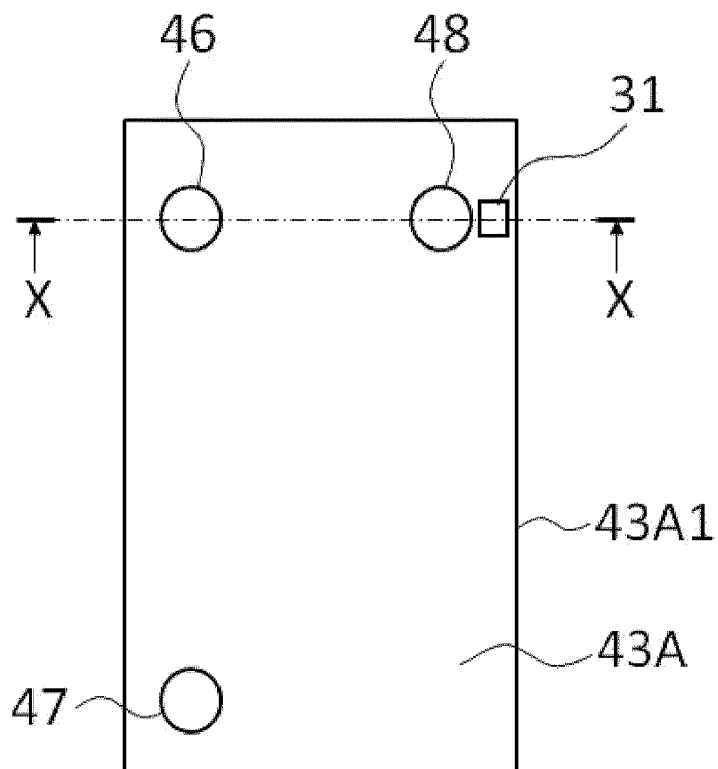


FIG. 10

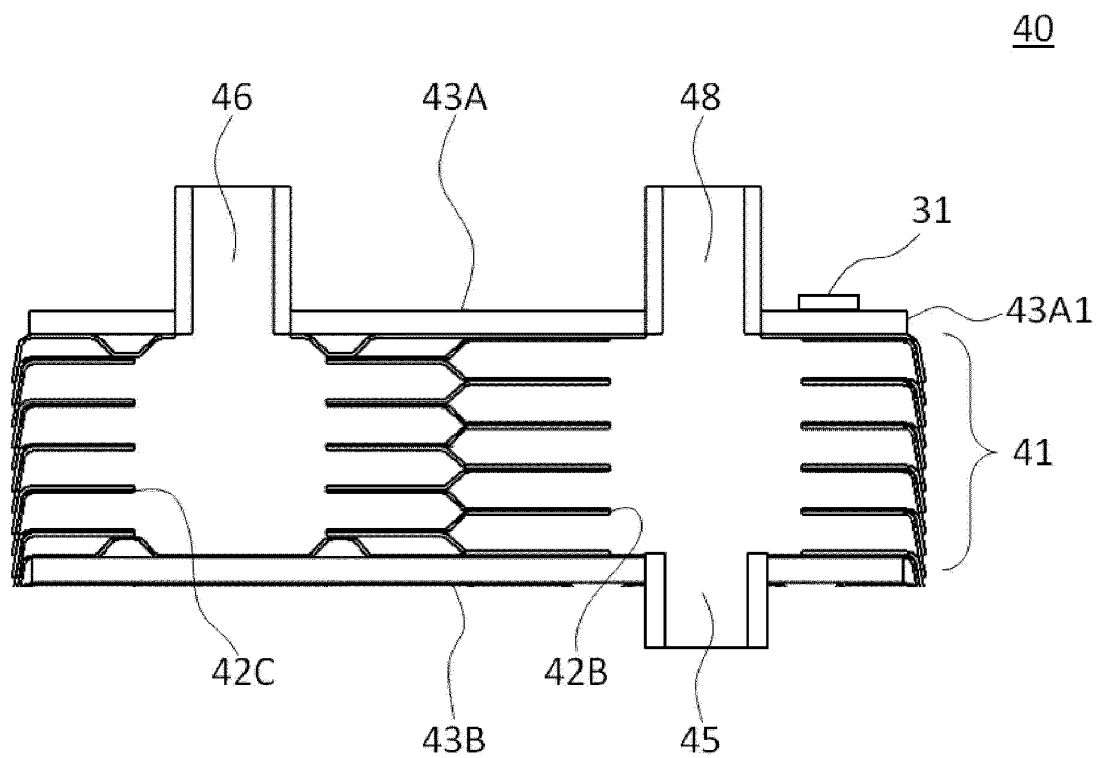
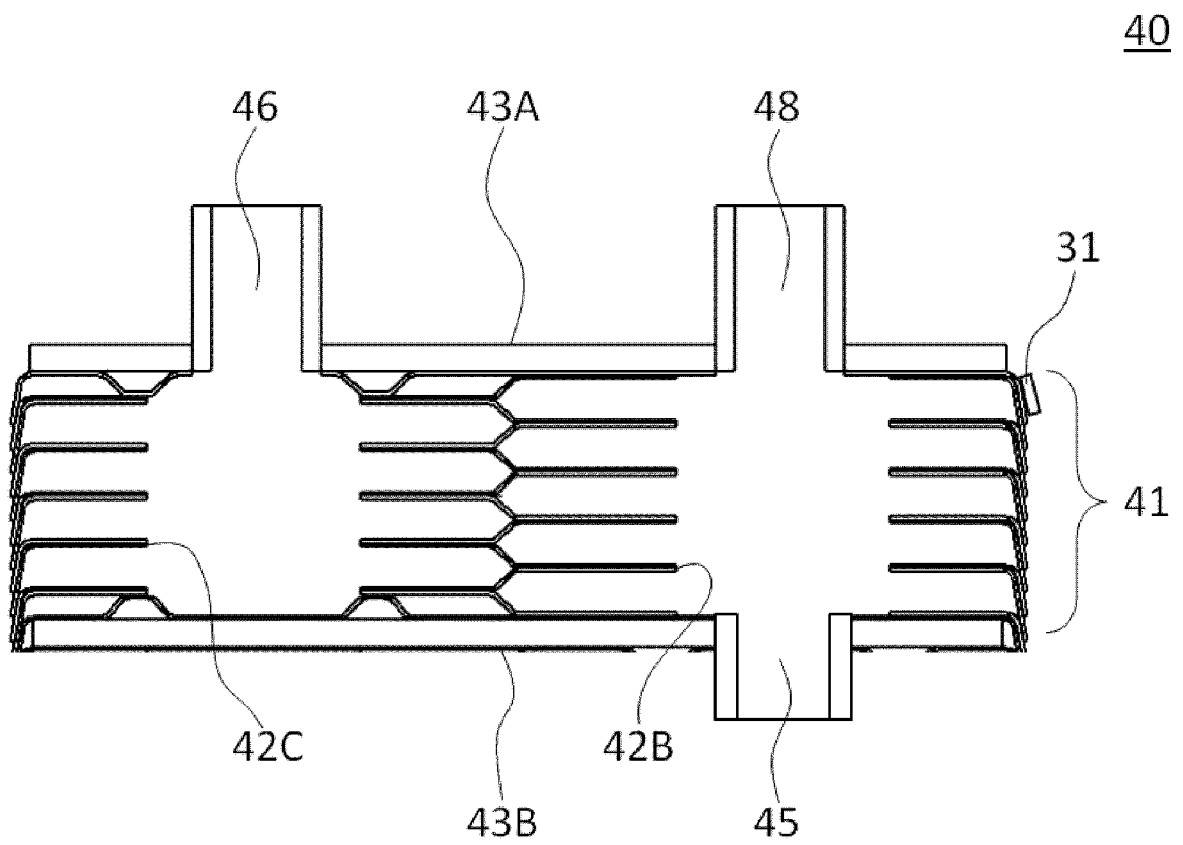


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/039230

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F28D9/02 (2006.01) i, F25B1/00 (2006.01) n, F25B41/04 (2006.01) n,
F25B49/02 (2006.01) n

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. F28D9/02, F25B1/00, F25B41/04, 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.
X	JP 2018-136058 A (CALSONIC KANSEI CORPORATION) 30	1
Y	August 2018, paragraphs [0010]-[0036], fig. 1-3	2-3, 6, 8-15
A	(Family: none)	4-5, 7
Y	JP 2005-188765 A (SANYO ELECTRIC CO., LTD.) 14	2-3, 8, 11-15
A	July 2005, paragraphs [0012], [0013], [0021], [0038], fig. 1, 2	4-5, 7
	& EP 1548377 A2, paragraphs [0044], [0045], [0053], [0072], fig. 1, 2 & KR 10-2005-0065382 A & CN 1637362 A	



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
14.11.2019

Date of mailing of the international search report
26.11.2019

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/039230

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	Relevant to claim No.
Category*	Citation of document, with indication, where appropriate, of the relevant passages	
Y A	JP 2011-89690 A (HITACHI APPLIANCES INC.) 06 May 2011, paragraphs [0024]-[0026], [0028], fig. 1, 5, 6 & CN 102042660 A	2, 6, 8, 11-15 4-5, 7
Y	JP 2018-40289 A (TOYOTA MOTOR CORPORATION) 15 March 2018, paragraph [0052] & US 2018/0066567 A1, paragraph [0073] & CN 107795367 A	8
Y	JP 5246041 B2 (PANASONIC CORPORATION) 24 July 2013, paragraphs [0016]-[0018], fig. 1, 2 (Family: none)	9-15
Y	WO 2018/105102 A1 (MITSUBISHI ELECTRIC CORPORATION) 14 June 2018, paragraph [0031] & EP 3351868 A1, paragraph [0032] & CN 110050160 A	12-15
Y	JP 2014-40945 A (KOBE STEEL, LTD.) 06 March 2014, paragraph [0089], fig. 13 & US 2014/0054022 A1, paragraph [0105], fig. 13 & EP 2700895 A1	14-15
Y	EP 1500896 A2 (INVENSYS PROCESS SYSTEMS A/S) 26 January 2005, paragraphs [0019]-[0022], fig. 1, 2a (Family: none)	15
A	CN 202630756 U (NINGBO HRALE HEAT EXCHANGE EQUIPMENT CO., LTD.) 26 December 2012, entire text, all drawings (Family: none)	1
A	KR 10-2017-0078003 A (SEO, J. W.) 07 July 2017, entire text, all drawings (Family: none)	1

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5246041 B [0003]