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(54) **REFRIGERATION CIRCUIT**

(57) Provided is a refrigeration circuit wherein surplus refrigerant created during an air-cooling operation can be accommodated when the capacity of an outdoor heat exchanger is less than the capacity of an indoor heat exchanger. In a refrigeration circuit (11), an indoor heat exchanger (51) is a cross-fin type heat exchanger and an outdoor heat exchanger (25) is a stacked heat exchanger. A refrigerant storage tank (27) is provided

between the outdoor heat exchanger (25) and an expansion valve (29). Because the capacity of the outdoor heat exchanger (25) is less than the capacity of the indoor heat exchanger (51), the surplus refrigerant is present during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank (27) in this refrigeration circuit (11), the surplus refrigerant is prevented from hindering refrigeration control.

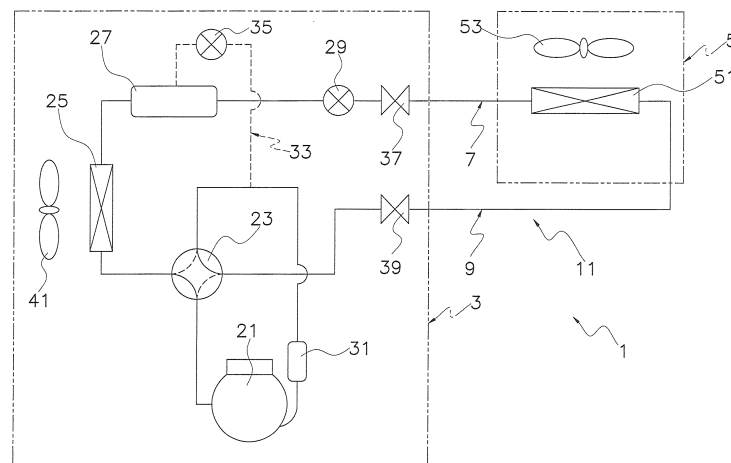


FIG. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration circuit, and particularly relates to a refrigeration circuit used in an air conditioner.

BACKGROUND ART

[0002] In a refrigeration circuit of an air conditioning apparatus, the optimal refrigerant quantity during an air-cooling operation is different from the optimal refrigerant quantity during an air-warming operation, and the capacity of an outdoor heat exchanger functioning as a condenser during the air-cooling operation is therefore different from the capacity of an indoor heat exchanger functioning as a condenser during the air-warming operation. Normally, the capacity of the outdoor heat exchanger is greater than the capacity of the indoor heat exchanger, and refrigerant that cannot be accumulated in the indoor heat exchanger during the air-warming operation is temporarily stored in an accumulator or the like.

SUMMARY OF THE INVENTION

<Technical Problem>

[0003] However, when a small high-performance capacitor such as is disclosed in Patent Literature 1 (Japanese Laid-open Patent Application No. 6-143991) is used in an outdoor heat exchanger of a refrigeration circuit of an air conditioning apparatus, the capacity of the outdoor heat exchanger is less than the capacity of the indoor heat exchanger, there will for the moment be refrigerant (surplus refrigerant) that could not be accommodated in the outdoor heat exchanger during the air-cooling operation, and the quantity of this refrigerant exceeds the quantity that can be stored in the accumulator or the like.

[0004] An object of the present invention is to provide a refrigeration circuit that can accommodate surplus refrigerant occurring during the air-cooling operation when the capacity of the outdoor heat exchanger is less than the capacity of the indoor heat exchanger.

<Solution to Problem>

[0005] A refrigeration circuit according to a first aspect of the present invention is a refrigeration circuit in which refrigerant flows sequentially to a compressor, an outdoor heat exchanger, an expansion valve, and an indoor heat exchanger during an air-cooling operation, and refrigerant flows sequentially to the compressor, the indoor heat exchanger, the expansion valve, and the outdoor heat exchanger during an air-warming operation; wherein the indoor heat exchanger is a cross-fin type heat exchanger and the outdoor heat exchanger is a stacked

heat exchanger. A refrigerant storage tank is provided between the outdoor heat exchanger and the expansion valve.

[0006] The capacity of the stacked heat exchanger is less than the capacity of the cross-fin type heat exchanger having the same heat exchange performance. In comparison with a refrigeration circuit in which both the outdoor heat exchanger and the indoor heat exchanger are cross-fin type heat exchangers, for example, when only the outdoor heat exchanger is replaced with a stacked heat exchanger having the same heat exchange performance, the capacity of the stacked heat exchanger is not only less than what would be the capacity of a cross-fin type outdoor heat exchanger, but is also less than the capacity of the cross-fin type indoor heat exchanger to which it is connected.

[0007] Due to the capacity of the outdoor heat exchanger being less than the capacity of the indoor heat exchanger, surplus refrigerant occurs during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank in this refrigeration circuit, the surplus refrigerant is prevented from hindering refrigeration control.

[0008] A refrigeration circuit according to a second aspect of the present invention is a refrigeration circuit in which refrigerant flows sequentially to a compressor, an outdoor heat exchanger, an expansion valve, and an indoor heat exchanger during an air-cooling operation, and refrigerant flows sequentially to the compressor, the indoor heat exchanger, the expansion valve, and the outdoor heat exchanger during an air-warming operation; wherein the capacity of the outdoor heat exchanger is 100% or less of the capacity of the indoor heat exchanger. A refrigerant storage tank is provided between the outdoor heat exchanger and the expansion valve.

[0009] In this refrigeration circuit, due to the capacity of the outdoor heat exchanger being equal to or less than the capacity of the indoor heat exchanger, surplus refrigerant occurs during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank, the surplus refrigerant is prevented from hindering refrigeration control.

[0010] A refrigeration circuit according to a third aspect of the present invention is the refrigeration circuit according to the first or second aspect, wherein the outdoor heat exchanger is a stacked heat exchanger having a plurality of flattened tubes and fins. The flattened tubes are arranged so as to overlap with spaces therebetween. The fins are placed between adjacent flattened tubes.

[0011] In this refrigeration circuit, similar to the refrigeration circuit according to the first or second aspect, the refrigerant quantity in the refrigeration circuit is reduced because the capacity of the outdoor heat exchanger is less than the capacity of the indoor heat exchanger. Surplus refrigerant occurs during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank, the surplus refrigerant is prevented from hindering refrigeration control.

[0012] A refrigeration circuit according to a fourth aspect of the present invention is the refrigeration circuit according to the first or second aspect, wherein the outdoor heat exchanger is a stacked heat exchanger having a flattened tube and fins. The flattened tube is molded into a serpentine shape. The fins are placed between mutually adjacent surfaces of the flattened tube.

[0013] In this refrigeration circuit, similar to the refrigeration circuit according to the first or second aspect, the refrigerant quantity in the refrigeration circuit is reduced because the capacity of the outdoor heat exchanger is less than the capacity of the indoor heat exchanger. Surplus refrigerant occurs during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank, the surplus refrigerant is prevented from hindering refrigeration control.

[0014] A refrigeration circuit according to a fifth aspect of the present invention is the refrigeration circuit according to the second aspect, wherein the outdoor heat exchanger and the indoor heat exchanger are both cross-fan type heat exchangers. The heat transfer tube diameter of the outdoor heat exchanger is less than the heat transfer tube diameter of the indoor heat exchanger.

[0015] In this refrigeration circuit, similar to the refrigeration circuit according to the second aspect, the refrigerant quantity in the refrigeration circuit is reduced because the capacity of the outdoor heat exchanger is less than the capacity of the indoor heat exchanger. Surplus refrigerant occurs during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank, the surplus refrigerant is prevented from hindering refrigeration control.

[0016] A refrigeration circuit according to a sixth aspect of the present invention is the refrigeration circuit according to the first or second aspect, wherein a bypass channel is also provided. The bypass channel leads a gas component of the refrigerant retained in the refrigerant storage tank to the compressor or to a refrigerant tube on the intake side of the compressor.

[0017] In this refrigeration circuit, during the air-warming operation, or in other words when the outdoor heat exchanger functions as an evaporator, the refrigerant is separated into a liquid and a gas in the refrigerant storage tank in front of the entrance of the outdoor heat exchanger, and the gas component heads to the bypass channel. As a result, the gas component, which does not contribute to evaporation, does not enter the outdoor heat exchanger, the refrigerant quantity flowing through the outdoor heat exchanger is reduced proportionately, and the pressure loss of the refrigerant in the outdoor heat exchanger is suppressed.

[0018] A refrigeration circuit according to a seventh aspect is the refrigeration circuit according to the sixth aspect, wherein the bypass channel has a flow-rate-regulating mechanism.

[0019] When the operating frequency of the compressor is high, there is a possibility that gas-liquid mixed refrigerant will return from the refrigerant storage tank to

the intake side of the compressor via the bypass channel, and will be drawn into the compressor. However, because a flow-rate-regulating mechanism is provided to the bypass channel in this refrigeration circuit, the liquid component of the gas-liquid mixed refrigerant is depressurized and evaporated. As a result, the liquid component is prevented from returning to the refrigerant tube on the intake side of the compressor.

[0020] In this refrigeration circuit, because refrigerant that has passed through the flow-rate-regulating mechanism evaporates in the outdoor heat exchanger and mixes with refrigerant heading to the compressor, when the flow-rate-regulating mechanism is an electric expansion valve, the state of the refrigerant immediately before being drawn into the compressor can be more optimally regulated by controlling the valve opening degree. Furthermore, in this refrigeration circuit, when the flow-rate-regulating mechanism is an electric expansion valve, the refrigerant quantity returning to the compressor can be increased or reduced by controlling the valve opening degree, and the refrigerant circulation quantity in the refrigeration circuit can therefore also be controlled in accordance with the load on the indoor heat exchanger side.

[0021] A refrigeration circuit according to an eighth aspect of the present invention is the refrigeration circuit according to the first or second aspect, wherein the refrigerant storage tank is a gas-liquid separator. In this refrigeration circuit, the gas-liquid separator has the function of separating liquid refrigerant and gas refrigerant in addition to the refrigerant storage function for retaining liquid refrigerant, and the refrigeration circuit is therefore simplified without the need for both a refrigerant storage container and a gas-liquid separator.

<Advantageous Effects of Invention>

[0022] In the refrigeration circuit according to any of the first through fifth aspects of the present invention, because the surplus refrigerant is accommodated in the refrigerant storage tank, the surplus refrigerant is prevented from hindering refrigeration control.

[0023] In the refrigeration circuit according to the sixth aspect of the present invention, the gas component, which does not contribute to evaporation, does not enter the outdoor heat exchanger, the refrigerant quantity flowing through the outdoor heat exchanger is reduced proportionately, and the pressure loss of the refrigerant in the outdoor heat exchanger is suppressed.

[0024] In the refrigeration circuit according to the seventh aspect of the present invention, the liquid component is prevented from returning to the refrigerant tube on the intake side of the compressor. The state of the refrigerant immediately before being drawn into the compressor can also be more optimally regulated. Furthermore, the refrigerant circulation quantity in the refrigeration circuit can therefore also be controlled in accordance with the load on the indoor heat exchanger side.

[0025] In the refrigeration circuit according to the eighth

aspect of the present invention, the gas-liquid separator has the function of separating liquid refrigerant and gas refrigerant in addition to the refrigerant storage function for retaining liquid refrigerant, and the refrigeration circuit is therefore simplified without the need for both a refrigerant storage container and a gas-liquid separator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

FIG. 1 is a structural view of an air conditioning apparatus provided with a refrigeration circuit according to an embodiment of the present invention;
FIG. 2 is a front view of an indoor heat exchanger;
FIG. 3 is an external perspective view of an outdoor heat exchanger;
FIG. 4 is a graph showing the ratio of outdoor heat exchanger capacity to indoor heat exchanger capacity in the refrigeration circuit, according to capability;
and
FIG. 5 is a simple cross-sectional view of a gas-liquid separator.

DESCRIPTION OF EMBODIMENTS

[0027] Embodiments of the present invention are described hereinbelow while referring to the drawings. The embodiments hereinbelow, which are specific examples of the present invention, do not limit the technological scope of the present invention.

(1) Air conditioning apparatus

(1-1) Overall configuration

[0028] FIG. 1 is a structural view of an air conditioning apparatus provided with a refrigeration circuit according to an embodiment of the present invention. In FIG. 1, an air conditioning apparatus 1, which is an air conditioning apparatus capable of an air-cooling operation and an air-warming operation, comprises an outdoor unit 3, an indoor unit 5, and a liquid refrigerant communication tube 7 and a gas refrigerant communication tube 9 for connecting the outdoor unit 3 with the indoor unit 5.

(1-2) Indoor unit

[0029] The indoor unit 5 has an indoor heat exchanger 51 and an indoor fan 53. The indoor heat exchanger 51, which is a cross-fin type heat exchanger, can evaporate or condense refrigerant flowing through the interior by heat exchange with indoor air, and can also cool or heat indoor air.

(1-2-1) Indoor heat exchanger

[0030] FIG. 2 is a front view of the indoor heat exchanger.

In FIG. 2, the indoor heat exchanger 51 comprises heat transfer fins 511 and heat transfer tubes 513. The heat transfer fins 511 are thin flat plates made of aluminum, and a plurality of through-holes are formed in one heat transfer fin 511. The heat transfer tubes 513 are composed of straight tubes 513a inserted through the through-holes of the heat transfer fins 511, and first U tubes 513b and second U tubes 513c for connecting the ends of adjacent straight tubes 513a to each other.

[0031] After being inserted into the through-hole of the heat transfer fins 511, the straight tubes 513a are expanded by a tube expander and adhered to the heat transfer fins 511. The straight tubes 513a and the first U tubes 513b are formed integrally, and the second U tubes 513c are joined to the ends of the straight tubes 513a by welding the like after the straight tubes 513a have been inserted into the through-hole of the heat transfer fins 511 and expanded.

(1-2-2) Indoor fan

[0032] The indoor fan 53 takes in indoor air and blows air to the indoor heat exchanger 51 by rotating, and facilitates heat exchange between the indoor heat exchanger 51 and the indoor air.

(1-3) Outdoor unit

[0033] In FIG. 1, the outdoor unit 3 has primarily a compressor 21, a four-way switching valve 23, an outdoor heat exchanger 25, a refrigerant storage tank 27, an expansion valve 29, a liquid-side shutoff valve 37, a gas-side shutoff valve 39, an accumulator 31, and a bypass channel 33. Furthermore, the outdoor unit 3 also has an outdoor fan 41.

(1-3-1) Compressor, four-way switching valve, and accumulator

[0034] The compressor 21 draws in and compresses gas refrigerant. The accumulator 31 is disposed in front of the intake port of the compressor 21, and liquid refrigerant is not drawn directly into the compressor 21.

[0035] The four-way switching valve 23 switches the direction of refrigerant flow when a switch is made between the air-cooling operation and the air-warming operation. During the air-cooling operation, the four-way switching valve 23 connects the discharge side of the compressor 21 and the gas side of the outdoor heat exchanger 25, and also connects the intake side of the compressor 21 and the gas-side shutoff valve 39. In other words, the state is as shown by the solid lines in the four-way switching valve 23 in FIG. 1.

[0036] During the air-warming operation, the four-way switching valve 23 connects the discharge side of the compressor 21 and the gas-side shutoff valve 39, and also connects the intake side of the compressor 21 and the gas side of the outdoor heat exchanger 25. In other

words, the state is as shown by the dashed lines in the four-way switching valve 23 in FIG. 1.

(1-3-2) Outdoor heat exchanger

[0037] The outdoor heat exchanger 25, which is a stacked heat exchanger, can condense or evaporate refrigerant flowing through the interior by heat exchange with outdoor air. The outdoor fan 41, which is disposed so as to face the outdoor heat exchanger 25, takes in outdoor air and blows air to the outdoor heat exchanger 25 by rotating, and facilitates heat exchange between the outdoor heat exchanger 25 and the outdoor air.

[0038] FIG. 3 is an external perspective view of the outdoor heat exchanger. In FIG. 3, the outdoor heat exchanger 25 has flattened tubes 251, corrugated fins 253, and headers 255.

[0039] The flattened tubes 251, which are formed from aluminum or an aluminum alloy, have flat parts 251a as heat transfer surfaces and a plurality of internal flow channels (not shown) through which refrigerant flows. A plurality of the flattened tubes 251 are arrayed with the flat parts 251a facing up and down.

[0040] The corrugated fins 253 are fins made of aluminum or an aluminum alloy and are bent into corrugations. The corrugated fins 253 are disposed in ventilation spaces enclosed between adjacent flattened tubes 251 above and below, and the dips and peaks thereof are in contact with the flat parts 251a of the flattened tubes 251. The dips, the peaks and the flat parts 251a are welded by soldering.

[0041] The headers 255 are joined to both ends of the flattened tubes 251 arrayed vertically in a plurality. The headers 255 have the function of supporting the flattened tubes 251, the function of leading refrigerant to the internal flow channels of the flattened tubes 251, and the function of gathering refrigerant that has exited the internal flow channels.

[0042] In the front view of FIG. 3, refrigerant flowing in from the entrance 255a of the right-side header 255 (referred to hereinafter as the first header) is distributed fairly equally to the internal flow channels of the highest flattened tube 251, and the refrigerant then flows to the left-side header 255 (referred to hereinafter as the second header). The refrigerant that has reached the second header is distributed equally to the internal flow channels of the second flattened tube 251, and the refrigerant then flows to the first header. Hereinafter the refrigerant in the odd-numbered flattened tubes 251 flows to the second header, and the refrigerant in the even-numbered flattened tubes 251 flows to the first header. The refrigerant in the lowest and even-numbered flattened tubes 251 flows to the first header where it is gathered and let out through the exit 255b.

[0043] When the outdoor heat exchanger 25 functions as an evaporator, the refrigerant flowing through the flattened tubes 251 absorbs heat from the air flowing through the ventilation spaces via the corrugated fins 253. When

the outdoor heat exchanger 25 functions as a condenser, the refrigerant flowing through the flattened tubes 251 loses heat to the air flowing through the ventilation spaces via the corrugated fins 253. In the present embodiment, the capacity of the outdoor heat exchanger 25 is less than the capacity of the indoor heat exchanger 51 due to the outdoor heat exchanger 25 being a stacked heat exchanger as described above.

[0044] FIG. 4 is a graph showing the ratio of outdoor heat exchanger capacity to indoor heat exchanger capacity in the refrigeration circuit, according to capability. In FIG. 4, $\diamond$ indicates a normal type of package air conditioner (a cross-fin type outdoor heat exchanger), $\blacklozenge$ indicates a thin outdoor heat exchanger type of package air conditioner (a stacked outdoor heat exchanger), Δ indicates a normal type of room air conditioner (a cross-fin type outdoor heat exchanger), and $\blacktriangle$ indicates a thin outdoor heat exchanger type of room air conditioner (a stacked outdoor heat exchanger).

[0045] The ratio of outdoor heat exchanger capacity to indoor heat exchanger capacity for a combination in which the outdoor heat exchanger and the indoor heat exchanger are both cross-fin type heat exchangers is less than 1.0 when only the outdoor heat exchanger is replaced with a stacked heat exchanger having a similar heat exchange performance, as shown in FIG. 4. This means that the capacity of the stacked heat exchanger is not only less than the capacity of the cross-fin type outdoor heat exchanger, but is also less than the capacity of the cross-fin type indoor heat exchanger connected thereto. Therefore, a surplus of refrigerant arises during the air-cooling operation. In the refrigeration circuit 11 of the present embodiment, the surplus refrigerant is accommodated in the refrigerant storage tank 27.

[0046] When the ratio of outdoor heat exchanger capacity to indoor heat exchanger capacity is 0.3 to 0.9, it is preferable to use the refrigerant storage tank 27 for accommodating the surplus refrigerant, but in cases in which the ratio of outdoor heat exchanger capacity to indoor heat exchanger capacity is 1.0 as well, stable refrigerant control is made possible by using the refrigerant storage tank 27.

(1-3-3) Refrigerant storage tank

[0047] The refrigerant storage tank 27 is a container capable of retaining surplus refrigerant. For example, in cases in which the liquid refrigerant quantity that can be accommodated in the indoor heat exchanger 51 during the air-warming operation when the indoor heat exchanger 51 functions as a condenser is 1100 cc, and the liquid refrigerant quantity that can be accommodated in the outdoor heat exchanger 25 during the air-cooling operation when the outdoor heat exchanger 25 functions as a condenser is 800 cc, the excess 300 cc of liquid refrigerant that could not be accommodated in the outdoor heat exchanger 25 during the air-cooling operation is temporarily accommodated in the refrigerant storage tank 27.

[0048] During the air-warming operation, for example, immediately before entering the refrigerant storage tank 27, the refrigerant contains a gas component produced when the refrigerant passed through the expansion valve 29, but after entering the refrigerant storage tank 27, the refrigerant is separated into liquid refrigerant and gas refrigerant, the liquid refrigerant is stored in the lower side, and the gas refrigerant is stored in the upper side.

(1-3-4) Expansion valve

[0049] To regulate refrigerant pressure and/or the refrigerant flow rate, the expansion valve 29 is connected to the tube between the refrigerant storage tank 27 and the liquid-side shutoff valve 37, and the expansion valve has the function of expanding the refrigerant during both the air-cooling operation and the air-warming operation.

(1-3-5) Bypass channel and flow rate regulation valve

[0050] The gas refrigerant separated in the refrigerant storage tank 27 passes through the bypass channel 33 and flows to the intake side of the compressor 21. The liquid refrigerant separated in the refrigerant storage tank 27 flows to the outdoor heat exchanger 25. A flow rate regulation valve 35 is connected at some point in the bypass channel 33. In the present embodiment, the flow rate regulation valve 35 is an electric expansion valve.

(1-3-6) Shutoff valves and refrigerant communication tubes

[0051] The liquid-side shutoff valve 37 and the gas-side shutoff valve 39 are connected respectively to the liquid refrigerant communication tube 7 and the gas refrigerant communication tube 9. The liquid refrigerant communication tube 7 connects the liquid side of the indoor heat exchanger 51 of the indoor unit 5 and the liquid-side shutoff valve 37 of the outdoor unit 3. The gas refrigerant communication tube 9 connects the gas side of the indoor heat exchanger 51 of the indoor unit 5 and the gas-side shutoff valve 39 of the outdoor unit 3.

[0052] As a result, a refrigeration circuit 11 is formed in which refrigerant flows sequentially to the compressor 21, the outdoor heat exchanger 25, the expansion valve 29, and the indoor heat exchanger 51 during the air-cooling operation, and refrigerant flows sequentially to the compressor 21, the indoor heat exchanger 51, the expansion valve 29, and the outdoor heat exchanger 25 during the air-warming operation.

(2) Flow of refrigerant during air-warming operation

[0053] In FIG. 1, during the air-warming operation, the four-way switching valve 23 connects the discharge side of the compressor 21 and the gas-side shutoff valve 39, and connects the intake side of the compressor 21 and the gas side of the outdoor heat exchanger 25. The open-

ing degree of the expansion valve 29 is narrowed. As a result, the outdoor heat exchanger 25 functions as an evaporator of refrigerant and the indoor heat exchanger 51 functions as a condenser of refrigerant.

[0054] In the refrigeration circuit 11 in this state, low-pressure refrigerant is drawn into the compressor 21, compressed to a high pressure, and then discharged. The high-pressure refrigerant discharged from the compressor 21 passes through the four-way switching valve 23, the gas-side shutoff valve 39, and the gas refrigerant communication tube 9, and enters the indoor heat exchanger 51. The high-pressure refrigerant that has entered the indoor heat exchanger 51 is condensed there by heat exchange with the indoor air. The indoor air is thereby heated.

[0055] Because the capacity of the indoor heat exchanger 51 is greater than the capacity of the outdoor heat exchanger 25, most of the liquid refrigerant is accommodated in a condenser (the indoor heat exchanger 51) during the air-warming operation. The high-pressure refrigerant condensed in the indoor heat exchanger 51 passes through the liquid refrigerant communication tube 7 and the liquid-side shutoff valve 37 and reaches the expansion valve 29.

[0056] The refrigerant is depressurized to a low pressure by the expansion valve 29, after which the refrigerant enters the refrigerant storage tank 27. Immediately before entering the refrigerant storage tank 27, the refrigerant contains a gas component produced when the refrigerant passed through the expansion valve 29, but after entering the refrigerant storage tank 27, the refrigerant is separated into liquid refrigerant and gas refrigerant, the liquid refrigerant is stored in the lower side, and the gas refrigerant is stored in the upper side.

[0057] Because the flow rate regulation valve 35 is open, the gas refrigerant passes through the bypass channel 33 and heads to the intake side of the compressor 21. The liquid refrigerant is sent to the outdoor heat exchanger 25 where it is evaporated by heat exchange with the outdoor air supplied by the outdoor fan 41. Most of the gas refrigerant does not enter through the entrance of the outdoor heat exchanger 25, the refrigerant quantity flowing through the outdoor heat exchanger 25 therefore decreases, and pressure loss is suppressed proportionately.

[0058] The low-pressure refrigerant evaporated in the outdoor heat exchanger 25 passes through the four-way switching valve 23 to be drawn back into the compressor 21.

(3) Flow of refrigerant during air-cooling operation

[0059] In FIG. 1, during the air-cooling operation, the four-way switching valve 23 connects the discharge side of the compressor 21 and the gas side of the outdoor heat exchanger 25, and also connects the intake side of the compressor 21 and the gas-side shutoff valve 39. The opening degree of the expansion valve 29 is nar-

rowed. As a result, the outdoor heat exchanger 25 functions as a condenser of refrigerant and the indoor heat exchanger 51 functions as an evaporator of refrigerant.

[0060] In the refrigerant circuit in such a state, the low-pressure refrigerant is taken into the compressor 21, compressed to a high pressure, and then discharged. The high-pressure refrigerant discharged from the compressor 21 is passed through the four-way switching valve 23 and sent to the outdoor heat exchanger 25.

[0061] The high-pressure refrigerant sent to the outdoor heat exchanger 25 there exchanges heat with the outdoor air and condenses. The high-pressure refrigerant condensed in the outdoor heat exchanger 25 is sent to the refrigerant storage tank 27. Because the capacity of the outdoor heat exchanger 25 is less than the capacity of the indoor heat exchanger 51, the condenser (the outdoor heat exchanger 25) is incapable of accommodating all of the liquid refrigerant during the air-cooling operation. Therefore, the liquid refrigerant that could not be accommodated in the outdoor heat exchanger 25 is retained in the refrigerant storage tank 27, and the refrigerant storage tank 27 is filled with the liquid refrigerant. Because the flow rate regulation valve 35 is closed, the liquid refrigerant does not flow to the bypass channel 33.

[0062] Liquid refrigerant that has left the refrigerant storage tank 27 is sent to the expansion valve 29 and depressurized to a low pressure. The low-pressure refrigerant depressurized in the expansion valve 29 passes through the liquid-side shutoff valve 37 and the liquid refrigerant communication tube 7 and enters the indoor heat exchanger 51.

[0063] The low-pressure refrigerant that has entered the indoor heat exchanger 51 there exchanges heat with the indoor air and evaporates. The indoor air is thereby cooled. The low-pressure refrigerant that has evaporated in the indoor heat exchanger 51 is passed through the gas refrigerant communication tube 9, the gas-side shutoff valve 39, and the four-way switching valve 23, and is again drawn into the compressor 21.

(4) Characteristics

(4-1)

[0064] In the refrigeration circuit 11, the indoor heat exchanger 51 is a cross-fin type heat exchanger and the outdoor heat exchanger 25 is a stacked heat exchanger. The refrigerant storage tank 27 is provided between the outdoor heat exchanger 25 and the expansion valve 29. Because the capacity of the outdoor heat exchanger 25 is less than the capacity of the indoor heat exchanger 51, surplus refrigerant occurs during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank 27 in this refrigeration circuit, the surplus refrigerant is prevented from hindering refrigeration control.

(4-2)

[0065] In the refrigeration circuit 11, the capacity of the outdoor heat exchanger 25 is 100% or less of the capacity of the indoor heat exchanger 51. The refrigerant storage tank 27 is provided between the outdoor heat exchanger 25 and the expansion valve 29. Due to the capacity of the outdoor heat exchanger 25 being equal to or less than the capacity of the indoor heat exchanger 51, surplus refrigerant is present during the air-cooling operation, but because the surplus refrigerant is accommodated in the refrigerant storage tank, the surplus refrigerant is prevented from hindering refrigeration control.

(4-3)

[0066] In the refrigeration circuit 11, the bypass channel 33 is provided. The bypass channel 33 leads the gas component of the refrigerant retained in the refrigerant storage tank 27 to the compressor 21 or to the refrigerant tube on the intake side of the compressor 21. During the air-warming operation, i.e. when the outdoor heat exchanger 25 functions as an evaporator, the refrigerant is separated into a liquid and a gas in the refrigerant storage tank 27 before the entrance of the outdoor heat exchanger 25, and the gas component heads toward the bypass channel. As a result, the gas component which does not contribute to evaporation does not enter the outdoor heat exchanger 25, the refrigerant quantity flowing through the outdoor heat exchanger 25 decreases, and pressure loss of the refrigerant in the outdoor heat exchanger 25 is suppressed proportionately.

(4-4)

[0067] When the operating frequency of the compressor 21 is high, there is a possibility that gas-liquid mixed refrigerant from the refrigerant storage tank 27 will return to the intake side of the compressor 21 via the bypass channel 33 and be drawn into the compressor 21, but because the flow rate regulation valve 35 is provided to the bypass channel 33, the liquid component of the gas-liquid mixed refrigerant is depressurized and evaporated. As a result, the liquid component is prevented from returning to the refrigerant tube on the intake side of the compressor 21.

(4-5)

[0068] Refrigerant that has passed through the flow rate regulation valve 35 merges with the refrigerant that evaporates in the outdoor heat exchanger 25 and heads toward the compressor 21; therefore, when the flow rate regulation valve 35 is an electric expansion valve, the state of the refrigerant immediately before it is drawn into the compressor 21 can be more optimally regulated by controlling the valve opening degree.

(4-6)

[0069] Furthermore, when the flow rate regulation valve 35 is an electric expansion valve, the refrigerant quantity returning to the compressor 21 can be increased or reduced by controlling the valve opening degree, and it is therefore also possible to control the refrigerant circulation quantity of the refrigeration circuit 11 in accordance with the load in the side having the indoor heat exchanger 51.

(5) Modifications

[0070] There follows a description of a modification in which the refrigerant storage tank 27 is a gas-liquid separator. FIG. 5 is a simple cross-sectional view of a gas-liquid separator. In FIG. 5, the gas-liquid separator is a cyclone type of separator, having a cylindrical container 271, a first connecting tube 273, a second connecting tube 275, and a third connecting tube 277.

[0071] The first connecting tube 273 is joined in tangent to the peripheral side wall of the cylindrical container 271, communicating the interior of the cylindrical container 271 and the expansion valve 29. The second connecting tube 275 is joined to the bottom wall of the cylindrical container 271, communicating the interior of the cylindrical container 271 and the outdoor heat exchanger 25. The third connecting tube 277 is joined to the ceiling wall of the cylindrical container 271, communicating the interior of the cylindrical container 271 and the bypass channel 33.

[0072] During the air-warming operation, refrigerant that has been depressurized in the expansion valve 29 into a gas-liquid mixed state flows into the cylindrical container 271 from the first connecting tube 273, eddying along the internal peripheral surface 271b of the peripheral side wall thereof, at which time the liquid refrigerant adheres to the internal peripheral surface 271b and the liquid refrigerant and gas refrigerant are efficiently separated.

[0073] The liquid refrigerant descends under gravity to be retained in the bottom, passes through the second connecting tube 275, and heads toward the outdoor heat exchanger 25. Meanwhile, the gas refrigerant rises while swirling, passes through the third connecting tube 277, and flows to the bypass channel 33.

[0074] During the air-cooling operation, high-pressure refrigerant that has condensed in the outdoor heat exchanger 25 to a saturated liquid flows into the cylindrical container 271 from the second connecting tube 275, and the cylindrical container 271 is filled with liquid refrigerant. The liquid refrigerant passes through the first connecting tube 273 and heads to the expansion valve 29. Meanwhile, some of the liquid refrigerant in the cylindrical container 271 passes through the third connecting tube 277 and heads to the bypass channel 33.

[0075] As described above, in the refrigeration circuit 11 according to the modification, because the refrigerant

storage tank 27 is a cyclone type of gas-liquid separator, liquid refrigerant adheres to the internal peripheral surface 271b of the gas-liquid separator while the refrigerant is swirling along the internal peripheral surface, and gas-liquid separation is performed efficiently.

[0076] In addition to the refrigerant storage function of retaining liquid refrigerant, the gas-liquid separator has the function of separating liquid refrigerant and gas refrigerant, and the refrigeration circuit is therefore simplified without the need to provide both a refrigerant storage container and a gas-liquid separator.

(6) Other embodiments

(6-1)

[0077] In the above embodiment, the outdoor heat exchanger 25 is a stacked heat exchanger having a plurality of flattened tubes 251 and corrugated fins 253, the flattened tubes 251 being arranged so as to overlap with spaces therebetween, and the corrugated fins 253 being placed between adjacent flattened tubes 251.

[0078] However, the outdoor heat exchanger 25 is not limited to a configuration such as the one described above, and the same effects as the above embodiment are achieved even with a configuration in which, for example, the flattened tubes are molded into a serpentine shape and the fins are placed between adjacent surfaces of flattened tubes.

(6-2)

[0079] In the case of a refrigeration apparatus in which the outdoor heat exchanger 25 is cooled by water during the air-cooling operation, the same effects as the above embodiment are achieved even with a configuration in which the outdoor heat exchanger 25 and the indoor heat exchanger 51 are both cross-fin type heat exchangers, and the heat transfer tubes of the outdoor heat exchanger 25 have smaller diameter than the heat transfer tubes of the indoor heat exchanger 51.

INDUSTRIAL APPLICABILITY

[0080] As described above, according to the present invention, because a simple refrigeration circuit of high performance is provided, the present invention is not limited to air conditioning apparatuses and is also useful in heat-pump type hot water supply equipment.

REFERENCE SIGNS LIST

[0081]

- 11 Refrigeration circuit
- 21 Compressor
- 25 Outdoor heat exchanger
- 27 Refrigerant storage tank

29 Expansion valve
 33 Bypass channel
 35 Flow rate regulation valve (flow-rate-regulating mechanism) 51 Indoor heat exchanger

a flattened tube molded into a serpentine shape; and
 fins placed between mutually adjacent surfaces of the flattened tube.

CITATION LIST

PATENT LITERATURE

[0082] [Patent Literature 1] Japanese Laid-open Patent Application No. 6-143991

Claims

1. A refrigeration circuit (11) in which refrigerant flows sequentially to a compressor (21), an outdoor heat exchanger (25), an expansion valve (29), and an indoor heat exchanger (51) during an air-cooling operation, and refrigerant flows sequentially to the compressor (21), the indoor heat exchanger (51), the expansion valve (29), and the outdoor heat exchanger (25) during an air-warming operation; wherein the indoor heat exchanger (51) is a cross-fin type heat exchanger, the outdoor heat exchanger (25) is a stacked heat exchanger; and a refrigerant storage tank (27) is provided between the outdoor heat exchanger (25) and the expansion valve (29).

2. A refrigeration circuit (11) in which refrigerant flows sequentially to a compressor (21), an outdoor heat exchanger (25), an expansion valve (29), and an indoor heat exchanger (51) during an air-cooling operation, and refrigerant flows sequentially to the compressor (21), the indoor heat exchanger (51), the expansion valve (29), and the outdoor heat exchanger (25) during an air-warming operation; wherein the capacity of the outdoor heat exchanger (25) is 100% or less of the capacity of the indoor heat exchanger (51); and a refrigerant storage tank (27) is provided between the outdoor heat exchanger (25) and the expansion valve (29).

3. The refrigeration circuit (11) according to claim 1 or 2, wherein the outdoor heat exchanger (25) is a stacked heat exchanger having:

a plurality of flattened tubes arranged so as to overlap with spaces therebetween; and fins placed between adjacent flattened tubes.

4. The refrigeration circuit (11) according to claim 1 or 2, wherein the outdoor heat exchanger (25) is a stacked heat exchanger having:

5. The refrigeration circuit (11) according to claim 2, wherein the outdoor heat exchanger (25) and the indoor heat exchanger (51) are both cross-fin type heat exchangers; and the heat transfer tube diameter of the outdoor heat exchanger (25) is set smaller than the heat transfer tube diameter of the indoor heat exchanger (51).

6. The refrigeration circuit (11) according to claim 1 or 2, also provided with:

a bypass channel (33) for leading a gas component of the refrigerant retained in the refrigerant storage tank (27) to the compressor (21) or to a refrigerant tube on the intake side of the compressor (21).

7. The refrigeration circuit (11) according to claim 6, wherein the bypass channel (33) has a flow-rate-regulating mechanism (35).

8. The refrigeration circuit (11) according to claim 1 or 2, wherein the refrigerant storage tank (27) is a gas-liquid separator.

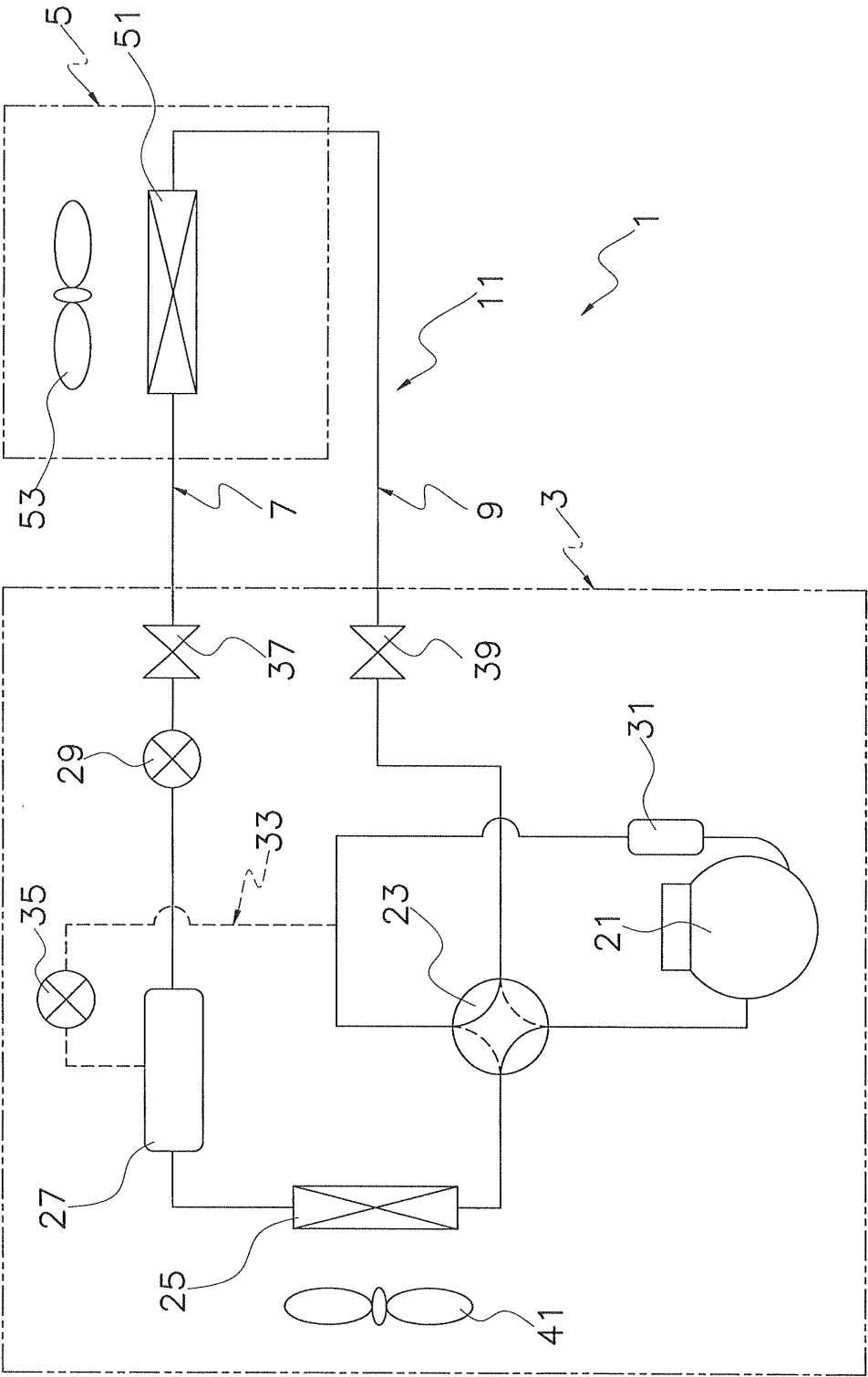


FIG. 1

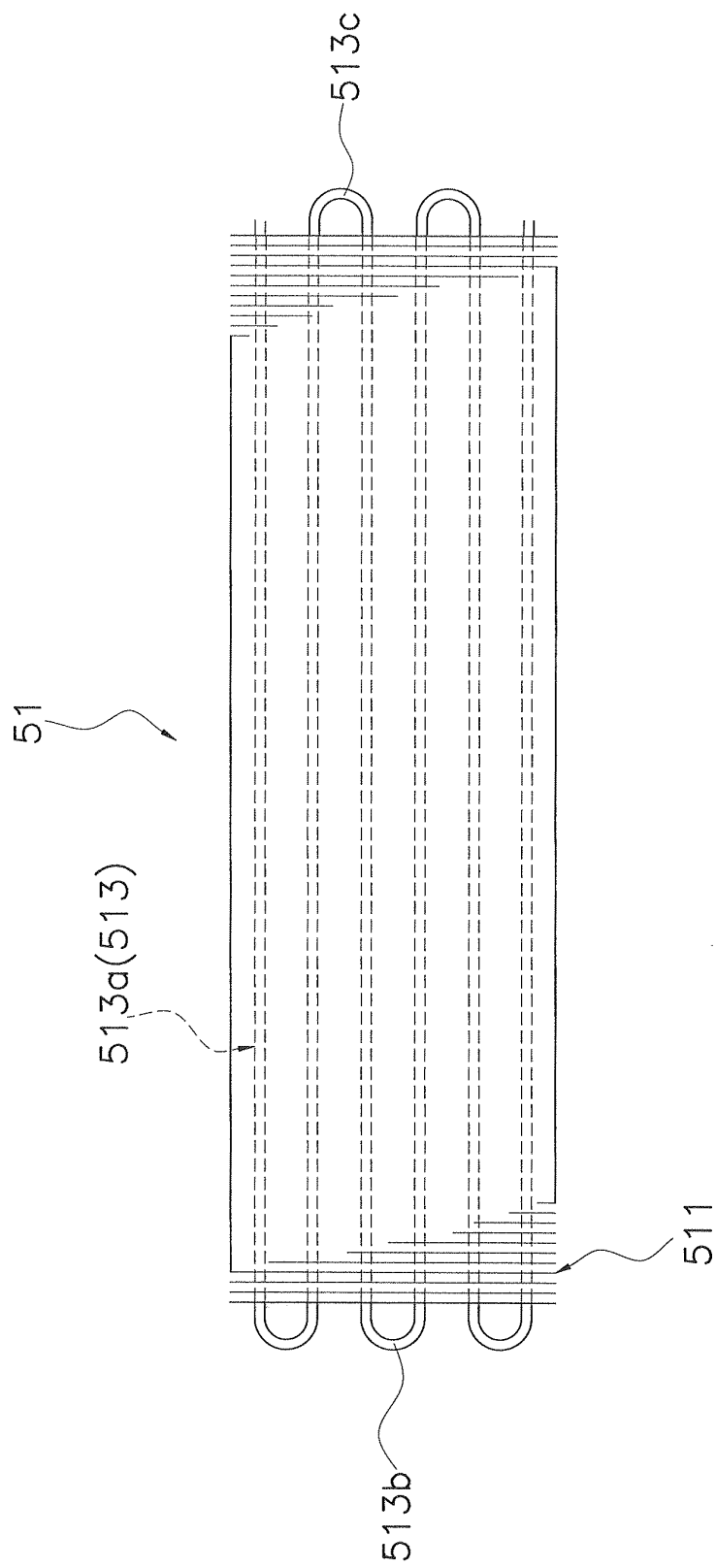


FIG. 2

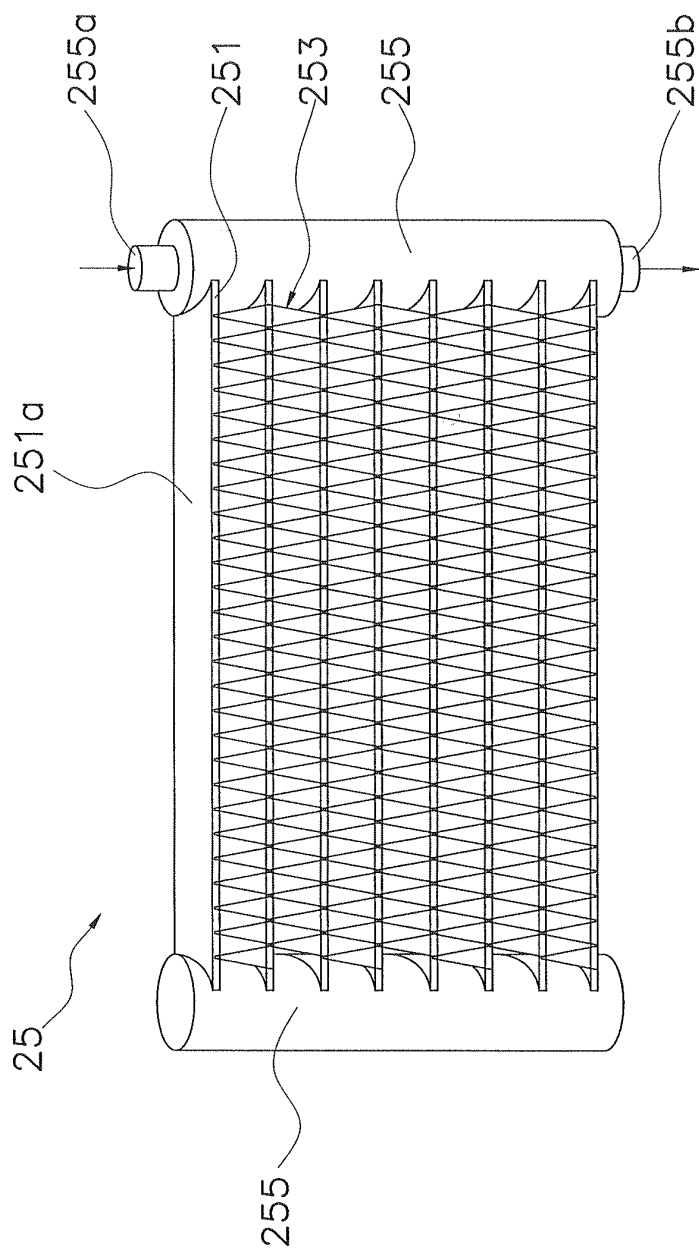


FIG. 3

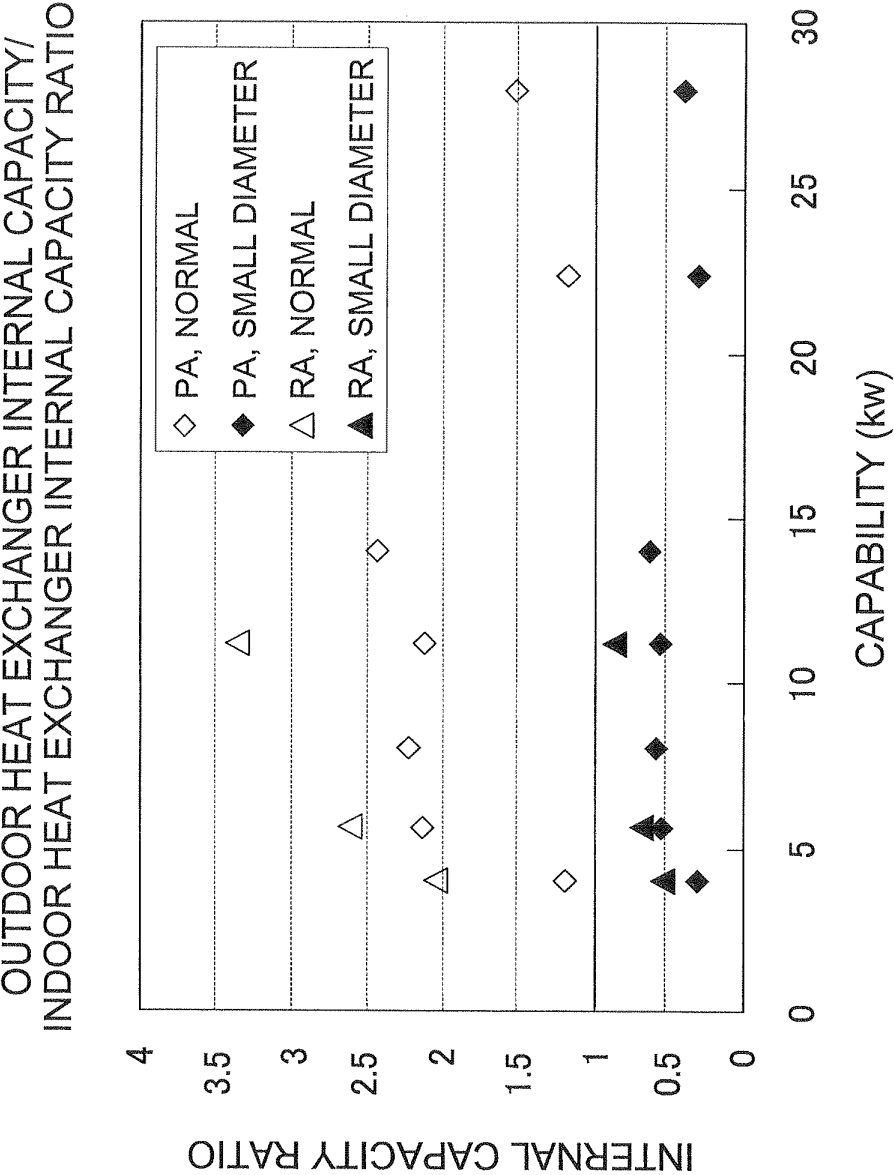


FIG. 4

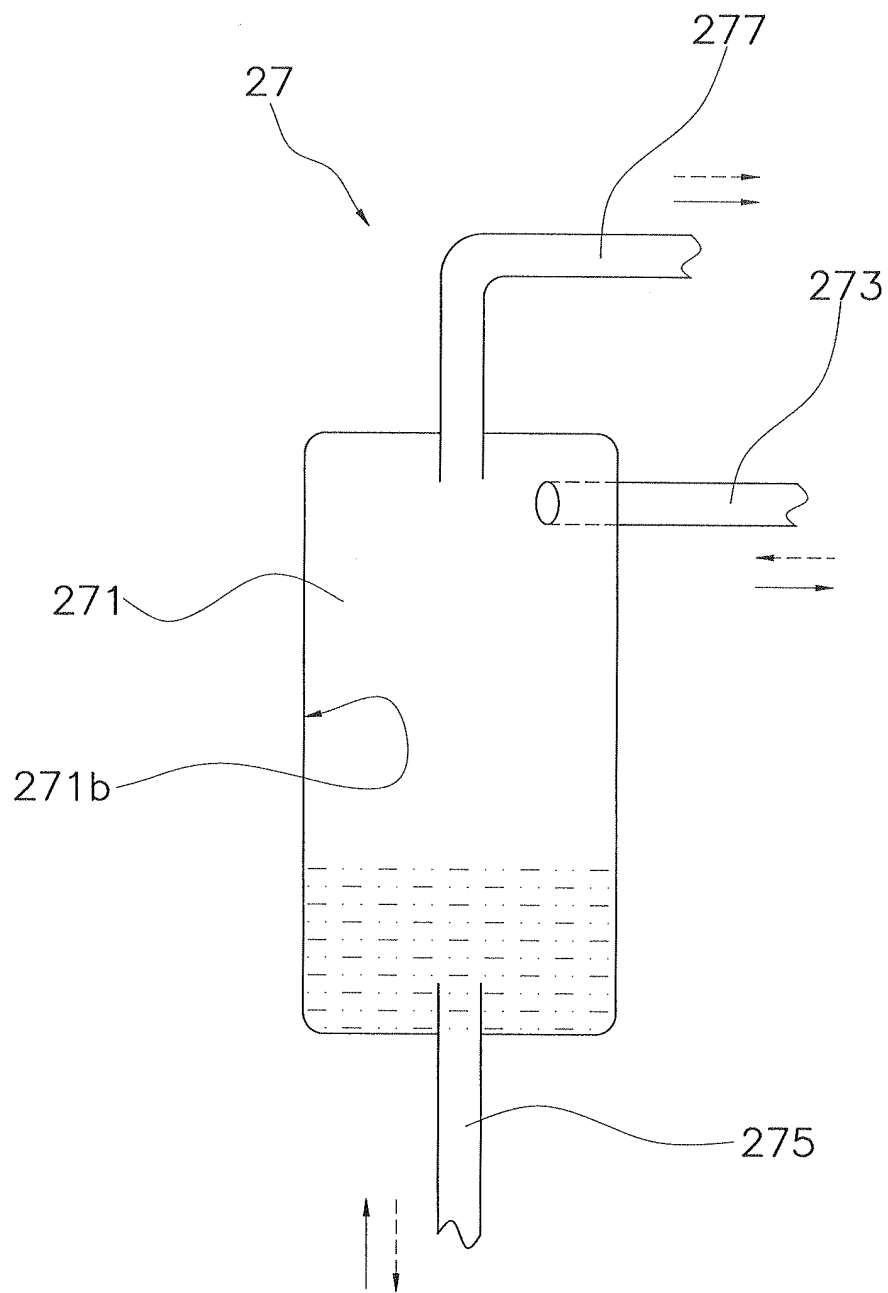


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/071612

A. CLASSIFICATION OF SUBJECT MATTER

F25B43/00 (2006.01) i, F25B1/00 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B43/00, F25B1/00Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2011
Kokai Jitsuyo Shinan Koho 1971-2011 Toroku Jitsuyo Shinan Koho 1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2006/013769 A1 (Daikin Industries, Ltd.), 09 February 2006 (09.02.2006), paragraphs [0024] to [0030]; fig. 1 & US 2008/0236189 A1 & EP 1775527 A1 & AU 2005268315 A & CN 1910409 A	1, 8 3
Y	JP 2008-89292 A (Daikin Industries, Ltd.), 17 April 2008 (17.04.2008), paragraphs [0057] to [0070]; fig. 1 to 3 & US 2009/0272135 A1 & EP 2068101 A1 & CN 101512256 A & AU 2007292606 B & CN 102080904 A & KR 10-2009-0064417 A	3
Y	JP 2007-285635 A (Hitachi Appliances, Inc.), 01 November 2007 (01.11.2007), paragraph [0013]; fig. 1 & CN 101059288 A	3

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search
06 December, 2011 (06.12.11)Date of mailing of the international search report
20 December, 2011 (20.12.11)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/071612

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The search revealed that the invention in claim 1 is the invention disclosed in the document 1 (WO 2006/013769 A1), and the invention at which a person skilled in the art can easily arrive from the matter disclosed in the document 1, and therefore, there is no same or corresponding special technical feature with respect to all of the inventions in claims 1-8.

(continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1, 3, 8

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/071612

Continuation of Box No.III of continuation of first sheet (2)

The requirement of unity of invention is not inquired for the inventions in claims 1, 3 and 8 (excluding the portions referring to claim 2), while any technical relationship within the meaning of PCT Rule 13 cannot be found between the inventions in claims 2, 4-7 and the inventions in all claims referring to claim 2 which are different from one another since there is no other matter common to claim 1, and the inventions in claims 2, 4-7 and the inventions in all claims referring to claim 2, which is considered to be a special technical feature within the meaning of PCT Rule 13.2, second sentence, between those inventions.

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 6143991 A [0003] [0082]