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(54) **REFRIGERATION CYCLE DEVICE**

(57) To provide a refrigeration cycle apparatus in which a subcooling circuit can exhibit sufficient performance using a simple configuration. A refrigeration cycle apparatus 1 is provided with a refrigerant pipe 8 that connects a compressor 2, an outdoor heat exchanger 3, a subcooling circuit 5, an indoor expansion valve 6, and an indoor heat exchanger 7 and through which a refrigerant is caused to flow. The refrigerant pipe 8 includes: a main circuit pipe 31 for circulating the refrigerant through the compressor 2, the outdoor heat exchanger 3, the subcooling circuit 5, the indoor expansion valve 6, and the indoor heat exchanger 7; a bypass circuit pipe 32 branching from the middle of the main circuit pipe 31 connecting the subcooling circuit 5 to the indoor expansion valve 6 and bypassing the refrigerant to the compressor 2; and a branch section 33 between the main circuit pipe 31 and the bypass circuit pipe 32. The branch section 33 includes an upstream pipe section 51, a main circuit branch pipe section 52 that branches upward from the upstream pipe section 51 and extends toward the indoor expansion valve 6, and a bypass circuit branch pipe section 53 that branches downward from the upstream pipe section 51 and extends toward the subcooling circuit 5.

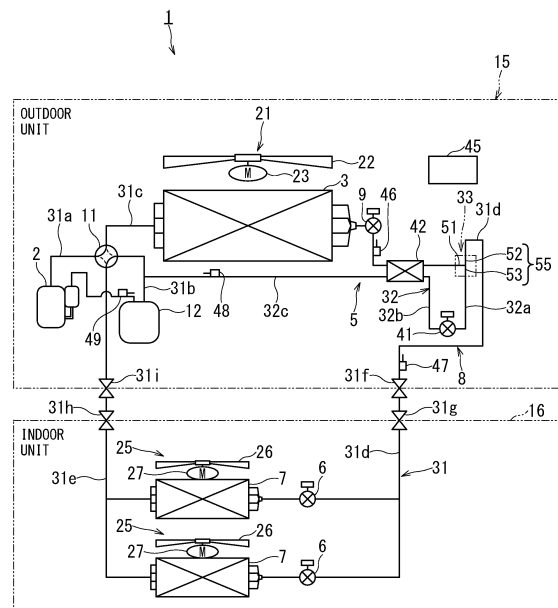


FIG. 1

Description

TECHNICAL FIELD

[0001] Embodiments of the present invention relates to a refrigeration cycle apparatus.

BACKGROUND

[0002] A known refrigeration cycle apparatus includes a subcooling circuit, and a gas-liquid separator provided on the upstream side of the subcooling circuit.

[0003] The conventional refrigeration cycle apparatus separates a refrigerant in gas-liquid two-phase state into a gas refrigerant and a liquid refrigerant by the gas-liquid separator, causes only the separated liquid refrigerant to flow into the subcooling circuit, and bypasses the separated gas refrigerant to a compressor.

PRIOR ART Document

PATENT DOCUMENT

[0004] [Patent Document 1] JP 2005-233551 A

SUMMARY

PROBLEMS TO BE SOLVED BY INVENTION

[0005] The conventional refrigeration cycle apparatus requires the gas-liquid separator and piping that bypasses the separated gas refrigerant to the compressor. These gas-liquid separator and bypass-piping increase the cost of the refrigeration cycle apparatus and complicate the piping system.

[0006] For this reason, the present invention proposes a refrigeration cycle apparatus that can sufficiently exhibit performance of a subcooling circuit with a simple configuration.

MEANS FOR SOLVING PROBLEM

[0007] To achieve the above object, an aspect of the present invention provides a refrigeration cycle apparatus including: a compressor; a condenser; an indoor expansion valve; a subcooling circuit that is disposed between the condenser and the indoor expansion valve; an evaporator; and a refrigerant pipe that connects the compressor, the condenser, the subcooling circuit, the indoor expansion valve, and the evaporator, and circulates a refrigerant. The refrigerant pipe includes: a main circuit pipe that circulates the refrigerant through the compressor, the condenser, the subcooling circuit, the indoor expansion valve, and the evaporator; a bypass circuit pipe that branches from the middle of the main circuit pipe connecting the subcooling circuit to the indoor expansion valve and bypasses the refrigerant to the compressor; and a branch portion that connects the main circuit pipe

and the bypass circuit pipe. The branch portion includes: an upstream pipe portion; a main-circuit branch pipe portion that branches upward from the upstream pipe portion toward the indoor expansion valve; and a bypass-circuit branch pipe portion that branches downward from the upstream pipe portion and extends toward the subcooling circuit.

[0008] It may be desired that the main-circuit branch pipe portion and the bypass-circuit branch pipe portion constitute a continuous straight pipe; and the upstream pipe portion is connected to the straight pipe in a tee-shape.

[0009] It may be desired that a flow-path cross-sectional area of the straight pipe is twice a flow-path cross-sectional area of the upstream pipe portion or more.

[0010] It may be desired that the upstream pipe portion extends substantially in a horizontal direction; and the main-circuit branch pipe portion and the bypass-circuit branch pipe portion extend substantially in a vertical direction.

[0011] It may be desired that an extended line of a centerline of the upstream pipe portion intersects neither a centerline of the main-circuit branch pipe portion nor a centerline of the bypass-circuit branch pipe portion.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

Fig. 1 is a schematic diagram illustrating a refrigeration cycle apparatus according to one embodiment of the present invention.

Fig. 2 is a schematic diagram illustrating a subcooling circuit of the refrigeration cycle apparatus according to the embodiment of the present invention.

Fig. 3 is a diagram showing a comparison of heat exchange amount between the subcooling circuit of the refrigeration cycle apparatus according to the embodiment of the present invention and a subcooling circuit of a comparative example.

Fig. 4 is a cross-sectional view illustrating another aspect of a branch portion of the refrigeration cycle apparatus according to the embodiment of the present invention.

Fig. 5 is a cross-sectional view illustrating another aspect of the branch portion of the refrigeration cycle apparatus according to the embodiment of the present invention.

DETAILED DESCRIPTION

[0013] Embodiments of a refrigeration cycle apparatus according to the present invention will now be described by referring to Fig. 1 to Fig. 5. The same reference signs are given to identical or equivalent components in each figure.

[0014] Fig. 1 is a schematic diagram illustrating a refrigeration cycle apparatus according to one embodiment

of the present invention.

[0015] As shown in Fig. 1, the refrigeration cycle apparatus 1 according to the present embodiment is, for example, an air conditioner. The refrigeration cycle apparatus 1 includes: a compressor 2; an outdoor heat exchanger 3; an outdoor expansion valve 9; a subcooling circuit 5; an indoor expansion valve 6; an indoor heat exchanger 7; and a refrigerant pipe 8 that connects the compressor 2, the outdoor heat exchanger 3, the subcooling circuit 5, the indoor expansion valve 6, and the indoor heat exchanger 7 so as to circulate a refrigerant.

[0016] The refrigeration cycle apparatus 1 further includes: a four-way valve 11 that sends the refrigerant to be discharged from the compressor 2 to one of the outdoor heat exchanger 3 and the indoor heat exchanger 7, and causes the compressor 2 to suck in the refrigerant having passed through the other of the outdoor heat exchanger 3 and the indoor heat exchanger 7 again; and an accumulator 12 that is provided on the refrigerant pipe 8 between the four-way valve 11 and the compressor 2.

[0017] The refrigeration cycle apparatus 1 further includes: an outdoor unit 15 to be installed outside a building such as a house; and at least one indoor unit 16 to be installed inside the building. The refrigeration cycle apparatus 1 according to the present embodiment includes, for example, one outdoor unit 15 and a plurality of indoor units 16 to be connected in parallel to the outdoor unit 15.

[0018] The outdoor unit 15 houses the compressor 2, the outdoor heat exchanger 3, the outdoor expansion valve 9, the subcooling circuit 5, the four-way valve 11, and the accumulator 12. The outdoor unit 15 is provided with an outdoor blower 21 that sucks in air from the outside of the outdoor unit 15 and blows out the air having exchanged heat with the outdoor heat exchanger 3 to the outside of the outdoor unit 15. The outdoor blower 21 includes: a propeller fan 22 that faces the outdoor heat exchanger 3; and an electric motor 23 that rotationally drives the propeller fan 22.

[0019] The indoor unit 16 houses the expansion valve 6 and the indoor heat exchanger 7. The indoor unit 16 is provided with an indoor blower 25 that sucks in air from the outside of the indoor unit 16 and blows out the air having exchanged heat with the indoor heat exchanger 7 to the outside of the indoor unit 16. The indoor blower 25 includes: a propeller fan 26 that faces the indoor heat exchanger 7; and an electric motor 27 that rotationally drives the propeller fan 26.

[0020] Each of the outdoor heat exchanger 3 and the indoor heat exchanger 7 is, for example, a fin-and-tube type.

[0021] The outdoor heat exchanger 3 functions as a condenser when the refrigeration cycle apparatus 1 is operated for cooling, and functions as an evaporator when the refrigeration cycle apparatus 1 is operated for heating.

[0022] The indoor heat exchanger 7 functions as an evaporator when the refrigeration cycle apparatus 1 is

operated for cooling, and functions as a condenser when the refrigeration cycle apparatus 1 is operated for heating.

[0023] The compressor 2 compresses the refrigerant, then boosts the refrigerant, and then discharges the refrigerant. The compressor 2 may be, for example, a compressor that can change its operating frequency by known inverter control or a compressor that cannot change its operating frequency.

[0024] Each of the indoor expansion valve 6 and the outdoor expansion valve 9 is, for example, a Pulse Motor Valve (PMV). Each of the indoor expansion valve 6 and the outdoor expansion valve 9 can adjust its valve opening. The indoor expansion valve 6 functions as an expansion valve mainly during cooling operation, and functions as a subcooling-degree adjusting valve for the indoor heat exchanger 7 mainly during heating operation. The outdoor expansion valve 9 functions as an expansion valve mainly during heating operation, and functions as a subcooling-degree adjusting valve for the outdoor heat exchanger 3 mainly during cooling operation. Although it is not illustrated, each of the indoor expansion valve 6 and the outdoor expansion valve 9 includes: a valve body having a through hole; a needle capable of advancing and retreating with respect to the through hole; and a power source for advancing and retreating the needle, for example. When the through hole is closed with the needle, the indoor expansion valve 6 and the outdoor expansion valve 9 stop (block) the flow of the refrigerant in the refrigeration cycle apparatus 1. At this time, the indoor expansion valve 6 and the outdoor expansion valve 9 are in the closed state, and the opening degree of each of the indoor expansion valve 6 and the outdoor expansion valve 9 is the smallest. When the needle is situated farthest from the through hole, the amount of the refrigerant flow in the refrigeration cycle apparatus 1 is maximized and the opening degree of each of the indoor expansion valve 6 and the outdoor expansion valve 9 is the largest at this time.

[0025] The power source is, for example, a stepping motor. When the number of pulses to be inputted to the stepping motor is zero, the indoor expansion valve 6 and the outdoor expansion valve 9 are closed. When the number of pulses to be inputted to the stepping motor is the maximum pulse, the indoor expansion valve 6 and the outdoor expansion valve 9 reach the maximum opening degree. The maximum number of pulses is, for example, several hundred pulses such as 500 pulses.

[0026] The refrigerant pipe 8 connects the compressor 2, the accelerator 12, the four-way valve 11, the outdoor heat exchanger 3, the outdoor expansion valve 9, the subcooling circuit 5, the indoor expansion valve 6, and the indoor heat exchanger 7. The refrigerant pipe 8 includes: a main circuit pipe 31 that circulates the refrigerant through the compressor 2, the accelerator 12, the four-way valve 11, the outdoor heat exchanger 3, the outdoor expansion valve 9, the subcooling circuit 5, the indoor expansion valve 6, and the indoor heat exchanger

7; a bypass circuit pipe 32 that branches from the middle of the main circuit pipe 31 interconnecting the subcooling circuit 5 and the indoor expansion valve 6 so as to bypass the refrigerant to the compressor 2; and a branch portion 33 that branches the bypass circuit pipe 32 from the main circuit pipe 31.

[0027] The main circuit pipe 31 includes: a first main refrigerant pipe 31a that connects the discharge side of the compressor 2 and the four-way valve 11; a second main refrigerant pipe 31b that connects the suction side of the compressor 2 and the four-way valve 11; a third main refrigerant pipe 31c that connects the four-way valve 11 and the outdoor heat exchanger 3; a fourth main refrigerant pipe 31d that connects the outdoor heat exchanger 3 and the indoor heat exchanger 7; and a fifth main refrigerant pipe 31e that connects the indoor heat exchanger 7 and the four-way valve 11.

[0028] The fourth main refrigerant pipe 31d connects the outdoor heat exchanger 3 and the indoor heat exchanger 7 via a first pipe-connection-portion 31f of the outdoor unit 15 and a second pipe-connection-portion 31g of the indoor unit 16.

[0029] The fifth main refrigerant pipe 31e connects the indoor heat exchanger 7 and the four-way valve 11 via a third pipe-connection-portion 31h of the indoor unit 16 and a fourth pipe-connection-portion 31i of the outdoor unit 15.

[0030] The branch portion 33 is disposed in the middle of the fourth main refrigerant pipe 31d that connects the outdoor heat exchanger 3 and the first pipe-connection-portion 31f of the outdoor unit 15.

[0031] The accumulator 12 is provided in the middle of the second main refrigerant pipe 31b.

[0032] The outdoor expansion valve 9, the subcooling circuit 5, and the indoor expansion valve 6 are provided in the middle of the fourth main refrigerant pipe 31d. The subcooling circuit 5 is closer to the outdoor heat exchanger 3 than the indoor expansion valve 6. The outdoor expansion valve 9 is closer to the outdoor heat exchanger 3 than the subcooling circuit 5. The indoor expansion valve 6 is closer to the indoor heat exchanger 7 than the subcooling circuit 5. In other words, the outdoor expansion valve 9 is disposed between the outdoor heat exchanger 3 and the subcooling circuit 5. The subcooling circuit 5 is disposed between the outdoor heat exchanger 3 and the indoor expansion valve 6. The subcooling circuit 5 is disposed between the outdoor expansion valve 9 and the indoor expansion valve 6. In addition, the outdoor expansion valve 9 is disposed in the middle of the fourth main refrigerant pipe 31d that connects the outdoor heat exchanger 3 and the first pipe-connection-portion 31f of the outdoor unit 15. The subcooling circuit 5 is disposed in the middle of the fourth main refrigerant pipe 31d that connects the outdoor heat exchanger 3 and the first pipe-connection-portion 31f of the outdoor unit 15. The indoor expansion valve 6 is disposed in the middle of the fourth main refrigerant pipe 31d that connects the second pipe-connection-portion 31g of the indoor unit 16

and the indoor heat exchanger 7.

[0033] The four-way valve 11 switches the direction of the refrigerant flow in the refrigerant pipe 8. When the refrigeration cycle apparatus 1 is operated for cooling (with the flow of the refrigerant shown by the solid line in Fig. 1) to lower the room temperature in the building, the four-way valve 11 circulates the refrigerant from the first main refrigerant pipe 31a to the third main refrigerant pipe 31c and circulates the refrigerant from the fifth main refrigerant pipe 31e to the second main refrigerant pipe 31b. When the refrigeration cycle apparatus 1 is operated for heating (with the flow of the refrigerant shown by the broken line in Fig. 1) to raise the room temperature in the building, the four-way valve 11 circulates the refrigerant from the first main refrigerant pipe 31a to the fifth main refrigerant pipe 31e and circulates the refrigerant from the third main refrigerant pipe 31c to the second main refrigerant pipe 31b.

[0034] Fig. 2 is a schematic diagram illustrating the subcooling circuit of the refrigeration cycle apparatus according to the embodiment of the present invention.

[0035] As shown in Fig. 1 and Fig. 2, the subcooling circuit 5 of the refrigeration cycle apparatus 1 according to the present embodiment includes: the bypass circuit pipe 32; a subcooling expansion valve 41; and a subcooling heat exchanger 42.

[0036] The bypass circuit pipe 32 branches the refrigerant flowing from the outdoor heat exchanger 3 to the indoor heat exchanger 7 in the main circuit pipe 31 during the cooling operation, and bypasses the refrigerant to the accelerator 12 without passing through the indoor expansion valve 6 and the indoor heat exchanger 7. The bypass circuit pipe 32 branches from the branch portion 33, i.e., the middle of the fourth main refrigerant pipe 31d that connects the outdoor heat exchanger 3 and the first pipe-connection-portion 31f of the outdoor unit 15. The bypass circuit pipe 32 joins the second main refrigerant pipe 31b of the main circuit pipe 31 in the middle of the second main refrigerant pipe 31b that connects the accumulator 12 and the four-way valve 11.

[0037] The subcooling expansion valve 41 decompresses the refrigerant that has flowed from the branch portion 33 into the bypass circuit pipe 32.

[0038] The subcooling heat exchanger 42 exchanges heat between the refrigerant decompressed by the subcooling expansion valve 41 and the refrigerant flowing through the main circuit pipe 31 (specifically, the portion upstream of the branch portion 33 in the fourth main refrigerant pipe 31d) so as to subcool the refrigerant flowing through the main circuit pipe 31.

[0039] The bypass circuit pipe 32 includes: a first bypass refrigerant pipe 32a that connects the branch portion 33 and the subcooling expansion valve 41; a second bypass refrigerant pipe 32b that connects the subcooling expansion valve 41 and the subcooling heat exchanger 42; and a third bypass refrigerant pipe 32c that connects the subcooling heat exchanger 42 and the second main refrigerant pipe 31b of the main circuit pipe 31.

[0040] In addition, the refrigeration cycle apparatus 1 includes a controller 45 that is electrically connected to the four-way valve 11 via a signal line (not shown). The controller 45 may be connected to the compressor 2 that can change its operating frequency.

[0041] The controller 45 includes: a central processing unit (not shown) and a storage device (not shown) that stores various arithmetic programs and parameters to be executed by the central processing unit. The controller 45 reads various control programs from an auxiliary storage device into a main storage device, and causes the central processing unit to execute the various control programs having been read into the main storage device.

[0042] The controller 45 switches between the cooling operation and the heating operation of the refrigeration cycle apparatus 1 by switching the state of the four-way valve 11 on the basis of a request to be inputted into an input device such as a remote controller.

[0043] The controller 45 controls the opening degree of the subcooling expansion valve 41 on the basis of: a first temperature sensor 46 that measures temperature of the refrigerant flowing through the fourth main refrigerant pipe 31d between the outdoor heat exchanger 3 and the subcooling circuit 5; a second temperature sensor 47 that measures temperature of the refrigerant flowing through the fourth main refrigerant pipe 31d between the subcooling circuit 5 and the first pipe-connection-portion 31f; a third temperature sensor 48 that measures temperature of the refrigerant flowing through the third bypass refrigerant pipe 32c; and saturated suction temperature.

[0044] The saturated suction temperature is calculated by converting the value of a suction pressure sensor 49 that measures the pressure of the refrigerant flowing through the fourth main refrigerant pipe 31d.

[0045] During the cooling operation, the refrigeration cycle apparatus 1 discharges the compressed high-temperature and high-pressure refrigerant from the compressor 2, and then sends this refrigerant to the outdoor heat exchanger 3 via the four-way valve 11. The outdoor heat exchanger 3 exchanges heat between the air outside the building and the refrigerant passing through the tube, and cools the refrigerant in order to liquefy the refrigerant into a high-pressure liquefied refrigerant. That is, during the cooling operation, the outdoor heat exchanger 3 functions as a condenser. The refrigerant having passed through the outdoor heat exchanger 3 passes through the indoor expansion valve 6 so as to be depressurized and brought into a low-pressure gas-liquid two-phase refrigerant, and then reaches the indoor heat exchanger 7. The indoor heat exchanger 7 cools the air inside the building by exchanging heat between the air inside the building and the refrigerant passing through the tube. At this time, the indoor heat exchanger 7 functions as an evaporator that evaporates the refrigerant into a gaseous state. The refrigerant having passed through the indoor heat exchanger 7 is sucked back into the compressor 2.

[0046] During the heating operation, the refrigeration cycle apparatus 1 inverts the four-way valve 11 to generate a flow of refrigerant that is opposite to the flow of the refrigerant during the cooling operation in the refrigeration cycle, causes the indoor heat exchanger 7 to function as a condenser, and causes the outdoor heat exchanger 3 to function as an evaporator.

[0047] The refrigeration cycle apparatus 1 may be dedicated to cooling without the four-way valve 11. In this case, the discharge side of the compressor 2 is connected to the outdoor heat exchanger 3 through the refrigerant pipe 8, and the suction side of the compressor 2 is connected to the indoor heat exchanger 7 through the refrigerant pipe 8.

[0048] The subcooling circuit 5 is used for reducing the dryness of the refrigerant flowing from the outdoor heat exchanger 3 to the indoor expansion valve 6 and for reducing the amount of the refrigerant circulating in the indoor unit 16.

[0049] The subcooling circuit 5 is generally used in the cooling operation. In the subcooling circuit 5, a part of the liquid refrigerant condensed by the outdoor heat exchanger 3 is branched at the branch portion 33 and expanded at a low pressure by the subcooling expansion valve 41. The subcooling heat exchanger 42 exchanges heat between the two-phase refrigerant expanded at a low pressure by the subcooling expansion valve 41 and the refrigerant flowing through the main circuit pipe 31 (specifically, the portion upstream of the branch portion 33 in the fourth main refrigerant pipe 31d) so as to cool the refrigerant flowing through the main circuit pipe 31.

[0050] When a part of the refrigerant is not condensed in the outdoor heat exchanger 3 and flows out to the fourth main refrigerant pipe 31d in the state of gas refrigerant, there is a possibility that the two-phase refrigerant flows into the subcooling circuit 5. Generally, the subcooling expansion valve 41 has an insufficient pipe diameter for circulating the two-phase refrigerant. Accordingly, the amount of refrigerant flowing through the subcooling circuit 5 is insufficient, and thus, the heat exchange amount of the subcooling circuit 5 decreases. When the heat exchange amount of the subcooling circuit 5 decreases, the gas refrigerant is mixed into the fourth main refrigerant pipe 31d of the main circuit pipe 31 and the gas refrigerant is sent to the indoor unit 16.

[0051] For this reason, the branch portion 33 of the refrigeration cycle apparatus 1 according to the present embodiment includes: an upstream pipe portion 51; a main-circuit branch pipe portion 52 that branches upward (solid arrow U in Fig. 2) from the upstream pipe portion 51 and extends toward the indoor expansion valve 6; and a bypass-circuit branch pipe portion 53 that branches downward (solid arrow D in Fig. 2) from the upstream pipe portion 51 and extends towards the subcooling circuit 5. The upstream pipe portion 51 and the main-circuit branch pipe portion 52 correspond to a part of the fourth main refrigerant pipe 31d of the main circuit pipe 31, and the bypass-circuit branch pipe portion 53 corresponds to

a part of the first bypass refrigerant pipe 32a of the bypass circuit pipe 32.

[0052] The main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53 constitute a continuous straight pipe 55. In other words, the main-circuit branch pipe portion 52 configured as a part of the straight pipe 55 corresponds to a part of the fourth main refrigerant pipe 31d of the main circuit pipe 31, and the bypass-circuit branch pipe portion 53 configured as the rest of the straight pipe 55 corresponds to a part of the first bypass refrigerant pipe 32a of the bypass circuit pipe 32. The straight pipe 55 has a substantially uniform flow-path cross-sectional area from the portion corresponding to the main-circuit branch pipe portion 52 to the portion corresponding to the bypass-circuit branch pipe portion 53. The boundary between the fourth main refrigerant pipe 31d of the main circuit pipe 31 and the first bypass refrigerant pipe 32a of the bypass circuit pipe 32 is the confluence of the straight pipe 55 and the upstream pipe portion 51.

[0053] The fourth main refrigerant pipe 31d may be bent except the portion that corresponds to a part of the straight pipe 55. Additionally, the first bypass refrigerant pipe 32a may be bent except the portion that corresponds to the rest of the straight pipe 55.

[0054] The main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53 extend substantially in the vertical direction. The main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53 may be tilted in the range of 30 degrees (± 30 degrees) with respect to the vertical line VL.

[0055] The upstream pipe portion 51 is connected to the straight pipe 55 in a tee-shape. In other words, the upstream pipe portion 51 abuts on the straight pipe 55 from the radial direction of the straight pipe 55. The upstream pipe portion 51 extends substantially in the horizontal direction. The upstream pipe portion 51 may be tilted within a range of 45 degrees (± 45 degrees) with respect to the horizontal plane HP. The angle θ formed by the upstream pipe portion 51 and the straight pipe 55 is preferably 45 degrees or more.

[0056] For example, when the upstream pipe portion 51 abuts on the straight pipe 55 from the radial direction of the straight pipe 55, the angle θ formed by the upstream pipe portion 51 and the straight pipe 55 is 90 degrees. In this case, the upstream pipe portion 51 and the straight pipe 55 form a tee-shape rotated by 90 degrees.

[0057] The flow-path cross-sectional area PA1 of the straight pipe 55 is twice the flow-path cross-sectional area PA2 of the upstream pipe portion 51 or more.

[0058] The branch portion 33 of the refrigeration cycle apparatus 1 according to the present embodiment causes the mainstream (i.e., flow of the refrigerant flowing through the main circuit pipe 31) in the direction of the solid arrow A in Fig. 2, and causes a bypass flow (i.e., flow of the refrigerant flowing through the subcooling circuit 5) in the direction of the solid arrow B in Fig. 2. The amount of the refrigerant to be bypassed toward the sub-

cooling circuit 5 is determined by the inner diameter of the bypass circuit pipe 32 and the valve opening degree of the subcooling expansion valve 41. The amount of the refrigerant to be bypassed toward the subcooling circuit 5 is, for example, from 0% (when the subcooling expansion valve 41 is fully closed) to 20% (when the subcooling expansion valve 41 is fully open) of the mainstream. Thus, in the first bypass refrigerant pipe 32a, the gas refrigerant is separated upward and the liquid refrigerant is separated downward due to the influence of buoyancy and gravity. Accordingly, the proportion of the liquid refrigerant flowing into the subcooling circuit 5 increases, and the proportion of the gas refrigerant flowing into the subcooling circuit 5 decreases.

[0059] Once the flow rate of the liquid refrigerant flowing to the subcooling circuit 5 is secured, even if the gas-liquid two-phase refrigerant flows out from the outdoor heat exchanger 3, the gas-liquid two-phase refrigerant can be condensed into the liquid refrigerant by the subcooling circuit 5. That is, the outflow of the gas refrigerant to the side of the indoor unit 16 is eliminated or reduced.

[0060] When the flow-path cross-sectional area of the straight pipe 55 is twice the flow-path cross-sectional area of the upstream pipe portion 51 or more, the flow velocity of the refrigerant in the straight pipe 55 is reduced. This reduction effect reduces the flow velocity of the refrigerant in the first bypass refrigerant pipe 32a (i.e., flow velocity of the bypass flow) to, for example, about 10% of the flow velocity of the refrigerant in the fourth main refrigerant pipe 31d (i.e., flow velocity of the mainstream). This reduction of the flow velocity of the refrigerant makes the buoyancy of the gas refrigerant larger than the force to be received from the flow of the liquid refrigerant. Thus, the effect of gas-liquid separation appears more prominently.

[0061] Fig. 3 is a diagram showing a comparison of heat exchange amount between the subcooling circuit of the refrigeration cycle apparatus according to the embodiment of the present invention and a subcooling circuit of a comparative example.

[0062] The solid line α in Fig. 3 indicates the relationship between the dryness and the heat exchange amount in the subcooling circuit 5 of the refrigeration cycle apparatus 1 according to the present embodiment. The broken line β in Fig. 3 indicates the relationship between the dryness and the heat exchange amount in the subcooling circuit of the refrigeration cycle apparatus of the comparative example.

[0063] First, the branch portion of the refrigeration cycle apparatus in the comparative example is assumed to include: a main circuit pipe (corresponding to the fourth main refrigerant pipe 31d) that extends in the horizontal direction and connects the outdoor heat exchanger 3 to the indoor heat exchanger 7; and a bypass-circuit pipe (corresponding to the first bypass refrigerant pipe 32a) that hangs down from the lower face of the main circuit pipe and branches so as to be connected to the subcooling expansion valve 41. In other words, the refrigeration

cycle apparatus of the comparative example includes: the main circuit pipe; and a tee-shaped branch portion of the bypass-circuit pipe hanging down from a straight-pipe portion of the main circuit pipe.

[0064] As shown in Fig. 3, in the refrigeration cycle apparatus of the comparative example, the flow rate in the subcooling expansion valve is insufficient unless the dryness is zero or less. Thus, in the subcooling circuit of the comparative example, the heat exchange amount becomes insufficient when the dryness exceeds the zero value.

[0065] Even in the gas-liquid two-phase region where the dryness is larger than zero, the refrigeration cycle apparatus 1 according to the present embodiment can flow the liquid refrigerant through the subcooling expansion valve 41 by the gas-liquid separation effect of the branch portion 33. Thus, the subcooling circuit 5 according to the present embodiment can increase the heat exchange amount even if the dryness is larger than the zero value.

[0066] Fig. 4 and Fig. 5 are cross-sectional views illustrating another aspect of the branch portion of the refrigeration cycle apparatus according to the embodiment of the present invention. Fig. 4 is a cross-sectional view of passing through the center of the upstream pipe portion 51 of the branch portion 33 and orthogonal to the respective centers of the bypass-circuit branch pipe portion 53 and the main-circuit branch pipe portion 52. Fig. 5 is a cross-sectional view of passing through the respective centers of the bypass-circuit branch pipe portion 53 and the main-circuit branch pipe portion 52.

[0067] As shown in Fig. 4 and Fig. 5, the refrigeration cycle apparatus 1 according to the present embodiment includes a branch portion 33A. The extended line of the centerline Ca of the upstream pipe portion 51 of the branch portion 33A intersects neither the centerline Cb of the main-circuit branch pipe portion 52 nor the centerline Cc of the bypass-circuit branch pipe portion 53. In other words, the extended line of the centerline Ca of the upstream pipe portion 51 is biased outward in the radial direction of the main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53 with respect to the centerline Cb of the main-circuit branch pipe portion 52 and the centerline Cc of the bypass-circuit branch pipe portion 53.

[0068] It is preferred that the upstream pipe portion 51 is connected along the tangent TL of the bypass-circuit branch pipe portion 53 and the main-circuit branch pipe portion 52 in the cross-section of Fig. 4.

[0069] Further, it is preferred that the pipe diameter of the upstream pipe portion 51 is equal to or smaller than half the pipe diameter of the bypass-circuit branch pipe portion 53 and the main-circuit branch pipe portion 52.

[0070] In the branch portion 33A, the refrigerant flowing from the upstream pipe portion 51 into the straight pipe 55 (i.e., the main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53) causes a circumferential flow (solid arrow R) in the straight pipe 55. This

swirling flow R causes a separation effect between the gas refrigerant g and the liquid refrigerant 1 due to centrifugal force at the branch portion between the upstream pipe portion 51 and the straight pipe 55. Further, the swirling flow R reduces the flow velocity of the refrigerant in the longitudinal direction in the straight pipe 55. This reduction of the flow velocity makes it easier for the gas refrigerant to float upward and the liquid refrigerant to fall downward. That is, the supply ratio of the liquid refrigerant to the subcooling circuit 5 is improved.

[0071] The refrigeration cycle apparatus 1 according to the present embodiment has the branch portion 33 or 33A, and this branch portion 33 or 33A includes: the main-circuit branch pipe portion 52 that branches upward from the upstream pipe portion 51 and extends toward the indoor expansion valve 6; and a bypass-circuit branch pipe portion 53 that branches downward from the upstream pipe portion 51 and extends toward subcooling circuit 5. Consequently, even if the refrigerant in the state of gas-liquid two-phase flows out of the outdoor heat exchanger 3, the refrigeration cycle apparatus 1 increases the proportion of the liquid refrigerant flowing into the subcooling circuit 5 and decreases the proportion of the gas refrigerant flowing into the subcooling circuit 5. Once the flow rate of the liquid refrigerant flowing to the subcooling circuit 5 is satisfied, even if the refrigerant in the state of gas-liquid two-phase flows out of the outdoor heat exchanger 3, the refrigerant in the state of gas-liquid two-phase can be condensed into the liquid refrigerant by the subcooling circuit 5. That is, the refrigeration cycle apparatus 1 can eliminate or reduce the outflow of the gas refrigerant to the side of the indoor unit 16 by the branch portion 33 or 33A having a simple structure.

[0072] Additionally, the refrigeration cycle apparatus 1 according to the present embodiment includes: the straight pipe 55 configured with the main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53 continuously; and the upstream pipe portion 51 that is connected to the straight pipe 55 in the tee-shape. Consequently, the refrigeration cycle apparatus 1 can reduce the outflow of the gas refrigerant to the side of the indoor unit 16 by the branch portion 33 or 33A having an extremely simple structure.

[0073] Further, the refrigeration cycle apparatus 1 according to the present embodiment includes the straight pipe 55 having a flow-path cross-sectional area that is twice or more than twice the flow-path cross-sectional area of the upstream pipe portion 51. Consequently, the refrigeration cycle apparatus 1 can reduce the flow velocity of the refrigerant in the straight pipe 55. This reduction effect significantly reduces the flow velocity of the refrigerant in the first bypass refrigerant pipe 32a than the flow velocity of the refrigerant in the fourth main refrigerant pipe 31d. This reduction in the flow velocity of the refrigerant makes the buoyancy of the gas refrigerant larger than the force to be received from the flow of the liquid refrigerant. That is, the refrigeration cycle apparatus 1 can exert the effect of gas-liquid separation more

remarkably.

[0074] Moreover, the refrigeration cycle apparatus 1 according to the present embodiment includes: the upstream pipe portion 51 extending substantially horizontally; and the main-circuit branch pipe portion 52 and the bypass-circuit branch pipe portion 53, both of which extend substantially vertically. Consequently, the refrigeration cycle apparatus 1 can more reliably separate the refrigerant in the state of gas-liquid two-phase into the gas refrigerant and the liquid refrigerant, and introduce the separated liquid refrigerant into the subcooling circuit 5.

[0075] Furthermore, the refrigeration cycle apparatus 1 according to the present embodiment includes the upstream pipe portion 51, extended line of the centerline of which intersects neither the centerline of the main-circuit branch pipe portion 52 nor the centerline of the bypass-circuit branch pipe portion 53. Consequently, the refrigeration cycle apparatus 1 can generate a swirling flow in the branch portion 33A, and create a synergistic effect by the separation effect between the gas refrigerant and the liquid refrigerant using centrifugal force in addition to the separation effect between the gas refrigerant and the liquid refrigerant using gravity.

[0076] Therefore, according to the refrigeration cycle apparatus 1 of the present embodiment, the performance of the subcooling circuit 5 can be sufficiently exhibited by the simply configured branch portions 33 or 33A.

[0077] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

REFERENCE SIGNS LIST

[0078]

1	refrigeration cycle apparatus
2	compressor
3	outdoor heat exchanger
5	subcooling circuit
6	indoor expansion valve
7	indoor heat exchanger
8	refrigerant pipe
9	outdoor expansion valve
11	four-way valve
12	accumulator
15	outdoor unit
16	indoor unit
21	outdoor blower
22	propeller fan of the outdoor blower

23	electric motor of the outdoor blower
25	indoor blower
26	propeller fan of the indoor blower
27	electric motor of the indoor blower
5 31	main circuit pipe
31a	first main refrigerant pipe
31b	second main refrigerant pipe
31c	third main refrigerant pipe
31d	fourth main refrigerant pipe
10 31e	fifth main refrigerant pipe
31f	first pipe-connection-portion
31g	second pipe-connection-portion
31h	third pipe-connection-portion
31i	fourth pipe-connection-portion
15 32	bypass circuit pipe
32a	first bypass refrigerant pipe
32b	second bypass refrigerant pipe
32c	third bypass refrigerant pipe
33, 33A	branch portion
20 41	subcooling expansion valve
42	subcooling heat exchanger
45	controller
46	first temperature sensor
47	second temperature sensor
25 48	third temperature sensor
51	upstream pipe portion
52	main-circuit branch pipe portion
53	bypass-circuit branch pipe portion
55	straight pipe

Claims

1. A refrigeration cycle apparatus comprising:

a compressor;
a condenser;
an indoor expansion valve;
a subcooling circuit that is disposed between the condenser and the indoor expansion valve;
an evaporator; and
a refrigerant pipe that connects the compressor, the condenser, the subcooling circuit, the indoor expansion valve, and the evaporator, and circulates a refrigerant,
wherein the refrigerant pipe includes: a main circuit pipe that circulates the refrigerant through the compressor, the condenser, the subcooling circuit, the indoor expansion valve, and the evaporator; a bypass circuit pipe that branches from the middle of the main circuit pipe connecting the subcooling circuit to the indoor expansion valve and bypasses the refrigerant to the compressor; and a branch portion that connects the main circuit pipe and the bypass circuit pipe, and wherein the branch portion includes: an upstream pipe portion; a main-circuit branch pipe portion that branches upward from the upstream

pipe portion toward the indoor expansion valve;
and a bypass-circuit branch pipe portion that
branches downward from the upstream pipe
portion and extends toward the subcooling cir-
cuit.

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2. The refrigeration cycle apparatus according to claim 1, wherein:

the main-circuit branch pipe portion and the by-
pass-circuit branch pipe portion constitute a
continuous straight pipe; and
the upstream pipe portion is connected to the
straight pipe in a tee-shape.

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3. The refrigeration cycle apparatus according to claim 1 or claim 2, wherein a flow-path cross-sectional area of the straight pipe is twice a flow-path cross-sectional area of the upstream pipe portion or more.

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4. The refrigeration cycle apparatus according to any one of claim 1 to claim 3, wherein:

the upstream pipe portion extends substantially
in a horizontal direction; and
the main-circuit branch pipe portion and the by-
pass-circuit branch pipe portion extend substan-
tially in a vertical direction.

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5. The refrigeration cycle apparatus according to any one of claim 1 to claim 4, wherein an extended line of a centerline of the upstream pipe portion intersects neither a centerline of the main-circuit branch pipe portion nor a centerline of the bypass-circuit branch pipe portion.

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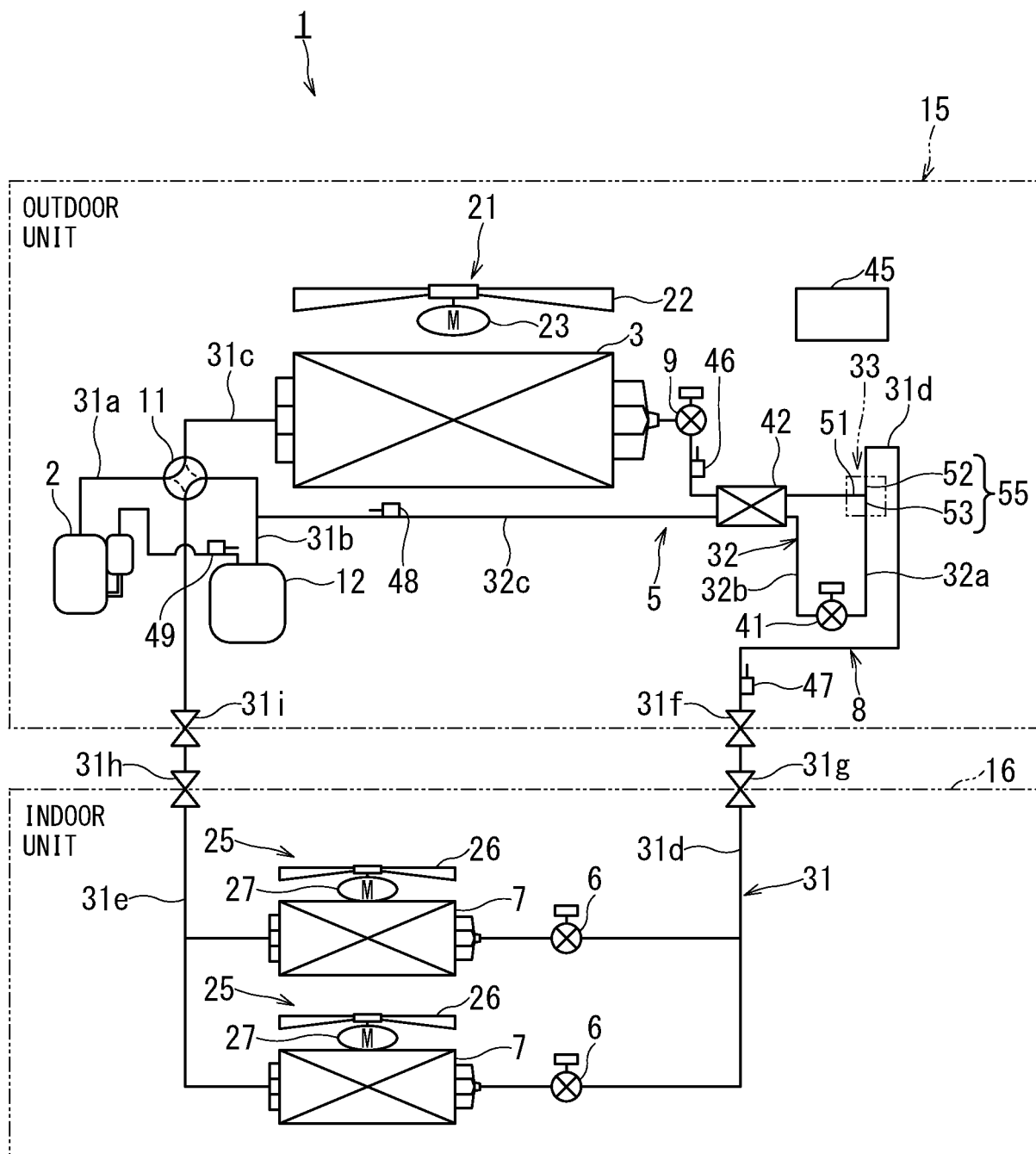


FIG. 1

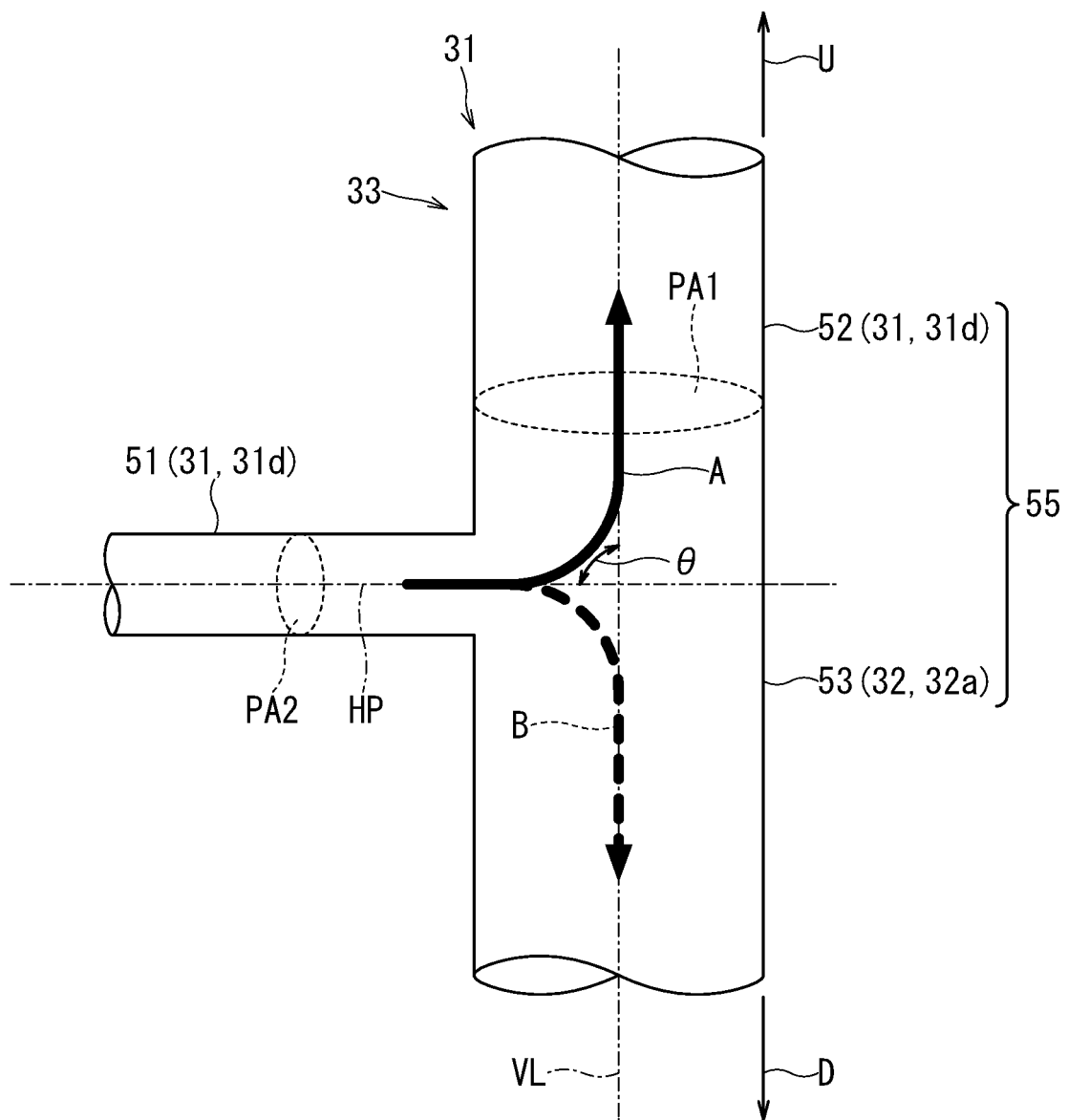


FIG. 2

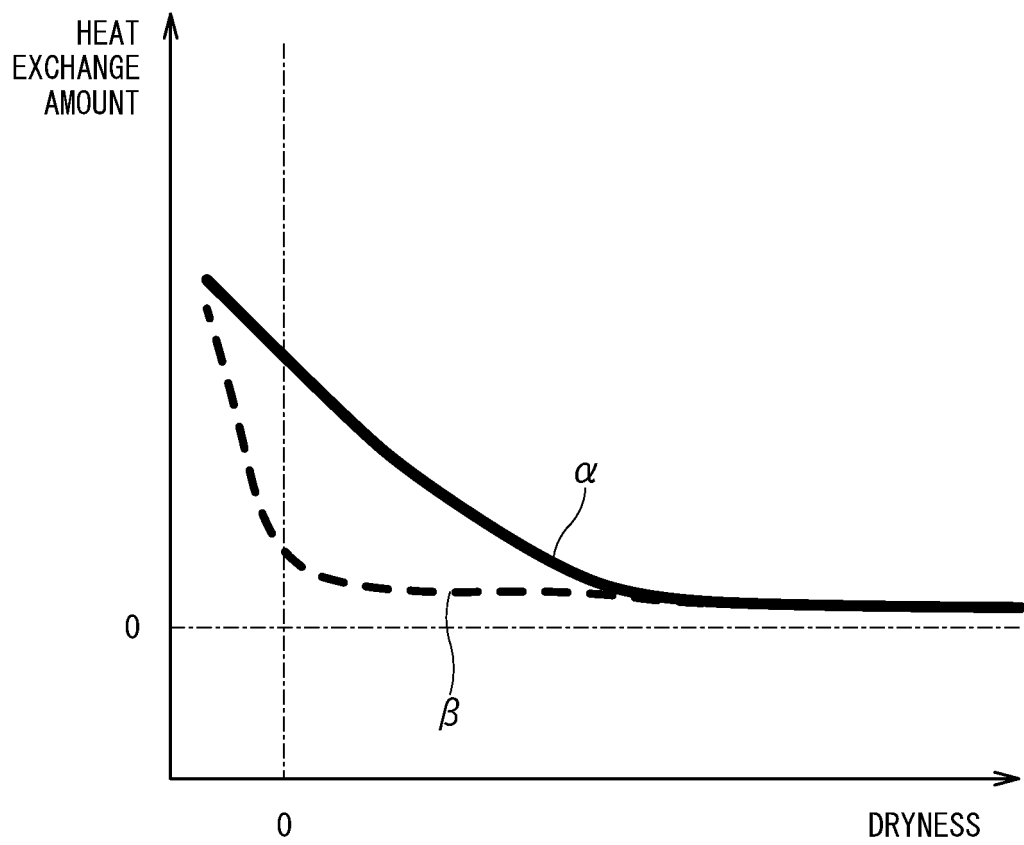


FIG. 3

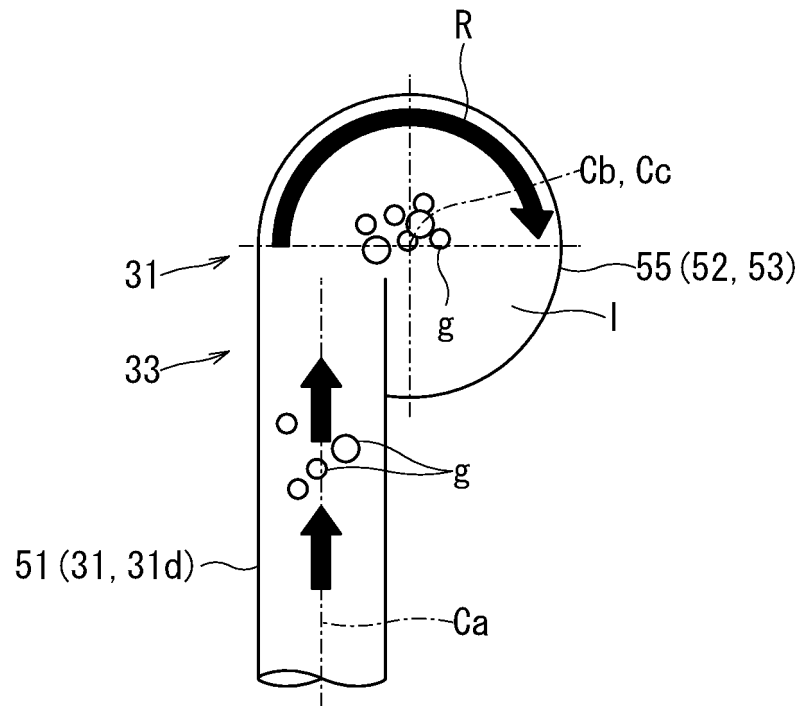


FIG. 4

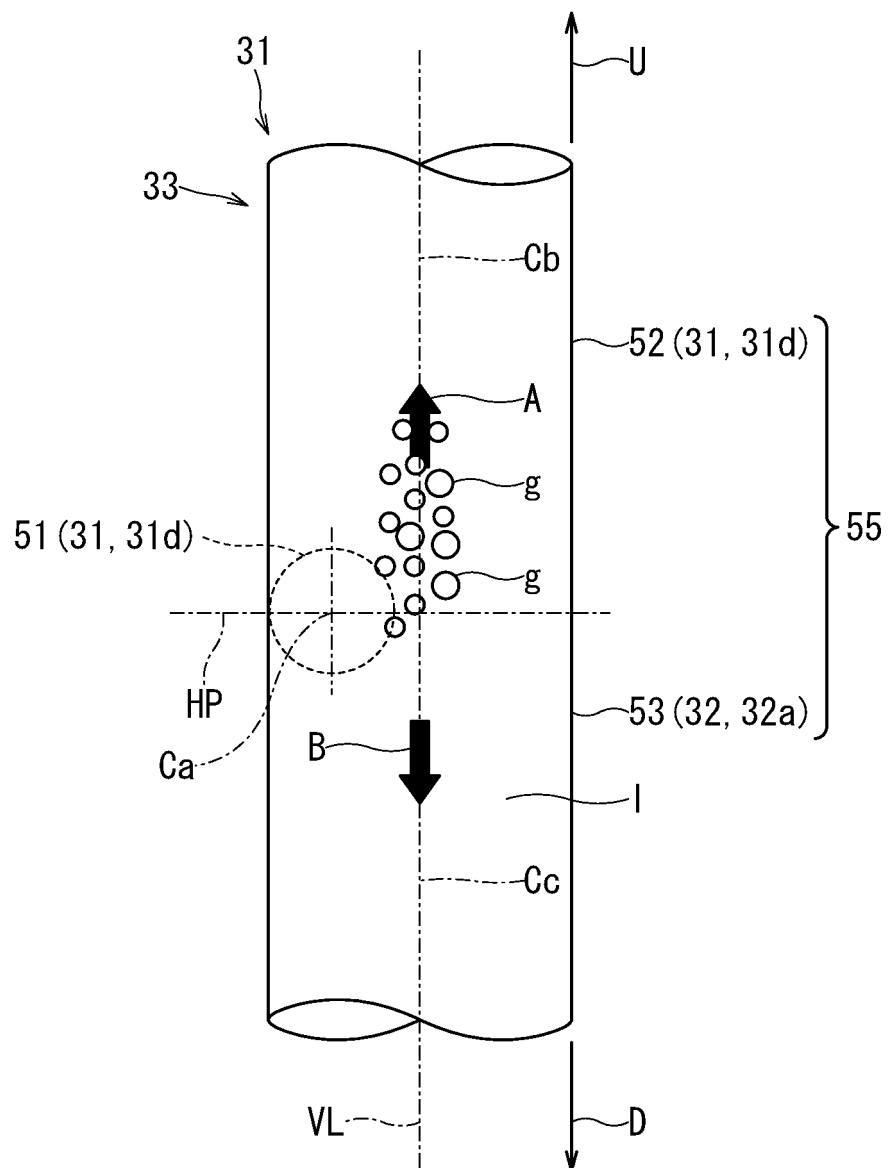


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/035376

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F25B1/00 (2006.01) i, F25B43/00 (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)

Int. Cl. F25B1/00, F25B43/00

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 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2015-143614 A (SAMSUNG R&D INSTITUTE JAPAN CO., LTD.) 06 August 2015, paragraphs [0009]-[0014], fig. 1 (Family: none)	1-5
Y	DE 2134939 A1 (GULF & WESTERN INDUSTRIES, INC.) 20 January 1972, description, page 8, line 22 to description, page 11, line 19, fig. 2 & FR 2101577 A	1-5



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

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"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

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

"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

27.11.2018

Date of mailing of the international search report

11.12.2018

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/035376

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 101886/1990 (Laid-open No. 061262/1992) (SHINMAYWA INDUSTRIES, LTD.) 26 May 1992, description, page 5, line 15 to description, page 8, line 11, fig. 1-3 (Family: none)	1-5
Y	JP 05-322383 A (DAIKIN INDUSTRIES, LTD.) 07 December 1993, claims, fig. 1-3 (Family: none)	1-5
Y	CN 205784060 U (TIANJIN UNIVERSITY) 07 December 2016, paragraph [0029], fig. 1 (Family: none)	2
Y	WO 2018/047511 A1 (MITSUBISHI ELECTRIC CORP.) 15 March 2018, paragraph [0147], fig. 51-53 (Family: none)	2
Y	JP 2000-179968 A (FUJITSU GENERAL LTD.) 30 June 2000, paragraph [0016], fig. 3 (Family: none)	2
A	JP 09-310925 A (HITACHI, LTD.) 02 December 1997, entire text, all drawings (Family: none)	1-5
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A	JP 2018-516355 A (GD MIDEA HEATING & VENTILATING EQUIPMENT CO., LTD.) 21 June 2018, entire text, all drawings & US 2017/0276407 A1 & WO 2017/071289 A1 & EP 3187789 A1 & CN 105240957 A	1-5

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REFERENCES CITED IN THE DESCRIPTION

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