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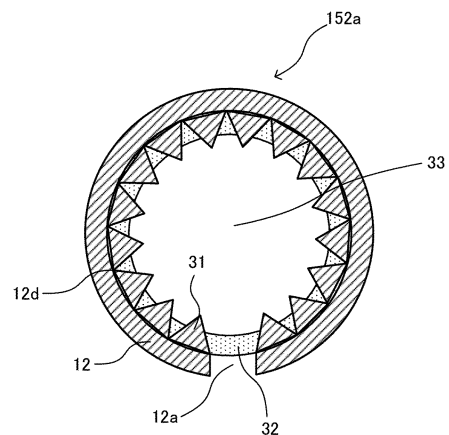
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(54) **REFRIGERANT DISTRIBUTOR, HEAT EXCHANGER, AND AIR CONDITIONER**

(57) A refrigerant distributor includes: an outer tube to which a heat transfer tube is connected; and an inner tube accommodated in the outer tube and having a dispersion hole that allows refrigerant to flow to the outer tube. The inner tube has an inner wall on which a projection is formed to extend in an extending direction of the inner tube. A plurality of projections including the projection are formed on the inner wall of the inner tube and arranged in a circumferential direction of the inner tube.

FIG. 4



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Description

Technical Field

[0001] The present disclosure relates to a refrigerant distributor having a double structure in which an inner pipe and an outer pipe are provided, and also to a heat exchanger and an air-conditioning apparatus that have such a refrigerant distributor.

Background Art

[0002] In the air-conditioning apparatus, liquid refrigerant condensed in a heat exchanger that is provided in an indoor unit and serves as a condenser is reduced in pressure by an expansion device. The refrigerant then changes into two-phase gas-liquid refrigerant and flows into a heat exchanger that is provided in an outdoor unit and serves as an evaporator.

[0003] When the two-phase gas-liquid refrigerant flows into the heat exchanger serving as the evaporator, a distribution function thereof for refrigerant is deteriorated. In view of this point, in a given method, in order to improve the distribution function for refrigerant, a flat tube of a heat exchanger provided in an outdoor unit is provided to face upward in a vertical direction, and a refrigerant distributor is provided to extend in a horizontal direction, thereby reducing the effect of gravity and improving the distribution of refrigerant (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Patent No. 6576577

Summary of Invention

Technical Problem

[0005] However, even in the case where the refrigerant distributor is provided to extend in the horizontal direction, the distribution function greatly varies depending on the flow rate or quality (dryness fraction) of refrigerant that flows in the refrigerant distributor. In particular, it should be noted that in the case where the flow rate and quality of the refrigerant are low, the two-phase gas-liquid refrigerant easily separates into liquid refrigerant and gas refrigerant. In the case where the liquid refrigerant does not uniformly flow along an inner wall of the inner pipe, only the liquid refrigerant or only gas refrigerant flows in a given region through dispersion holes formed in the inner wall, thus deteriorating the distribution function. In addition, the heat exchange performance of a heat exchanger and an air-conditioning apparatus that have such a refrigerant distributor as described above is re-

duced.

[0006] The present disclosure is applied in view of the above circumstances, and relates to a refrigerant distributor that uniformly distributes refrigerant to heat transfer tubes, and a heat exchanger and an air-conditioning apparatus that include such a refrigerant distributor.

Solution to Problem

[0007] A refrigerant distributor according to the present disclosure includes: an outer tube to which a heat transfer tube is connected; and an inner tube accommodated in the outer tube and having a dispersion hole that allows refrigerant to flow to the outer tube. The inner tube has an inner wall on which a projection is formed to extend in an extending direction of the inner tube. A plurality of projections including the projection are formed on the inner wall of the inner tube and arranged in a circumferential direction of the inner tube.

Advantageous Effects of Invention

[0008] According to the present disclosure, liquid refrigerant of two-phase gas-liquid refrigerant that flows in the inner tube is uniformly retained in a circumferential direction thereof between projections formed on an inner wall of the inner tube. As a result, the two-phase gas-liquid refrigerant uniformly flows through dispersion holes and is uniformly distributed to the heat transfer tube regardless the flow rate of the refrigerant.

Brief Description of Drawings

[0009]

[Fig. 1] Fig. 1 is a refrigerant circuit diagram schematically illustrating a configuration of a refrigerant circuit in a refrigeration cycle apparatus according to Embodiment 1.

[Fig. 2] Fig. 2 is a schematic sectional view of a first heat exchanger in the refrigeration cycle apparatus according to Embodiment 1 as viewed from the front.

[Fig. 3] Fig. 3 is a schematic sectional view of the first heat exchanger in the refrigeration cycle apparatus according to Embodiment 1 as viewed side-on.

[Fig. 4] Fig. 4 illustrates a cross section of an inner tube of a first refrigerant distributor in the refrigeration cycle apparatus according to Embodiment 1, the cross section being perpendicular to an extending direction of the inner tube.

[Fig. 5] Fig. 5 is an explanatory view for the extending direction of each of projections formed on an inner wall of the inner tube in the first refrigerant distributor in Embodiment 1.

[Fig. 6] Fig. 6 is an explanatory view for the extending direction of each of projections of a modification that are formed on the inner wall of the inner tube in the first refrigerant distributor according to Embodiment

1.

[Fig. 7] Fig. 7 illustrates a cross section of an inner tube in a first refrigerant distributor in a refrigeration cycle apparatus according to Embodiment 2, the cross section being perpendicular to an extending direction of the inner tube.

[Fig. 8] Fig. 8 is an explanatory view for the extending direction of each of projections formed on an inner wall of the inner tube in the first refrigerant distributor according to Embodiment 2.

[Fig. 9] Fig. 9 indicates the height of each of projections formed on an inner wall of an inner tube in a first refrigerant distributor according to Embodiment 3.

[Fig. 10] Fig. 10 is a cross-section view that is perpendicular to the extending direction of an inner tube and that indicates the positions of dispersion holes of the inner tube in a first refrigerant distributor according to Embodiment 4.

[Fig. 11] Fig. 11 is a schematic sectional view of a first heat exchanger in the refrigeration cycle apparatus according to Embodiment 5 as viewed from the front.

[Fig. 12] Fig. 12 is a schematic sectional view of a first heat exchanger of a refrigeration cycle apparatus according to Embodiment 6 as viewed from the front. Description of Embodiments

[0010] A heat exchanger including a refrigerant distributor according to each of embodiments will be described with reference to the drawings. It should be noted that in each of figures in the drawings, components that are the same as a previous figure or previous figures are denoted by the same reference signs, and after they are each explained once, their explanations will not be repeated except an explanation or explanations that need to be repeated.

Embodiment 1

[0011] Fig. 1 is a refrigerant circuit diagram schematically illustrating a configuration of a refrigerant circuit in a refrigeration cycle apparatus 200 according to Embodiment 1. A configuration and operation of the refrigeration cycle apparatus 200 will be described with reference to Fig. 1. The refrigeration cycle apparatus 200 according to Embodiment 1 includes, as elements of a refrigerant circuit, a first heat exchanger 152 provided with a first refrigerant distributor 152a, and a second heat exchanger 154 provided with a second refrigerant distributor 154a.

Configuration of Refrigeration Cycle Apparatus 200

[0012] As illustrated in Fig. 1, the refrigeration cycle apparatus 200 includes an outdoor unit 101 and an indoor unit 102. The outdoor unit 101 includes a compressor 100, a flow switching device 151, the first heat exchanger

152, and an expansion device 153. Furthermore, an accumulator 300 is provided upstream of the compressor 100. At the first heat exchanger 152, the first refrigerant distributor 152a is provided. The first refrigerant distributor 152a distributes refrigerant to heat transfer tubes 13 (see Fig. 2) of the first heat exchanger 152. In addition, an outdoor fan 156 is provided close to the first heat exchanger 152. The outdoor unit 101 further includes a controller 160.

[0013] The indoor unit 102 includes the second heat exchanger 154. At the second heat exchanger 154, the second refrigerant distributor 154a is provided. The second refrigerant distributor 154a distributes the refrigerant to heat transfer tubes (not illustrated) of the second heat exchanger 154. Furthermore, an indoor fan 157 is provided close to the second heat exchanger 154.

[0014] The compressor 100, the first heat exchanger 152, and the expansion device 153 are connected by pipes 155a, and the expansion device 153, the second heat exchanger 154, and the compressor 100 are connected by pipes 155b, whereby a refrigerant circuit is formed.

[0015] The compressor 100 compresses sucked refrigerant to cause the refrigerant to be in a high-temperature and high-pressure state. The refrigerant compressed by the compressor 100 is discharged from the compressor 100 and is sent to the first heat exchanger 152 or the second heat exchanger 154.

[0016] The flow switching device 151 switches the flow direction of the refrigerant between the flow direction of the refrigerant in a heating operation and that in a cooling operation. In the heating operation, the flow switching device 151 switches the flow direction of the refrigerant such that the refrigerant flows through a flow passage in which the compressor 100 is connected to the second heat exchanger 154, and in the cooling operation, the flow switching device 151 switches the flow direction of the refrigerant such that the refrigerant flows through a flow passage in which the compressor 100 is connected to the first heat exchanger 152. It should be noted that the flow switching device 151 is, for example, a four-way valve. However, a combination of two-way valves or three-way valves may be used as the flow switching device 151.

[0017] The first heat exchanger 152 serves as an evaporator in the heating operating operation, and serves as a condenser in the cooling operation. When the first heat exchanger 152 serves as an evaporator, at the first heat exchanger 152, heat exchange is performed between low-temperature and low-pressure refrigerant that flows out from the expansion device 153 and air sent from the outdoor fan 156, and liquid refrigerant of low-temperature and low-pressure two-phase gas-liquid refrigerant thus evaporates. When the first heat exchanger 152 serves as a condenser, at the first heat exchanger 152, heat exchange is performed between high-temperature and high-pressure refrigerant discharged from the compressor 100 and air sent from the outdoor fan 156, and high-

temperature and high-pressure gas refrigerant thus condenses. It should be noted that the first heat exchanger 152 may be a refrigerant-to-water heat exchanger. In this case, at the first heat exchanger 152, heat exchange is performed between the refrigerant and a heat medium such as water.

[0018] The expansion device 153 expands and decompresses refrigerant that flows out from the first heat exchanger 152 or the second heat exchanger 154. The expansion device 153 is, for example, an electric expansion valve that can adjust the flow rate of the refrigerant. It should be noted that as the expansion device 153, not only the electric expansion valve, but also a mechanical expansion valve that adopts a diaphragm as a pressure receiving part or a capillary tube can be applied.

[0019] The second heat exchanger 154 serves as a condenser in the heating operation, and serves as an evaporator in the cooling operation. When the second heat exchanger 154 serves as a condenser, at the second heat exchanger 154, heat exchange is performed between high-temperature and high-pressure refrigerant discharged from the compressor 100 and air sent from the indoor fan 157, and high-temperature and high-pressure gas refrigerant thus condenses. When the second heat exchanger 154 serves as an evaporator, at the second heat exchanger 154, heat exchange is performed between low-temperature and low-pressure refrigerant that flows out from the expansion device 153 and air sent from the indoor fan 157, and low-temperature and low-pressure liquid refrigerant of two-phase gas-liquid refrigerant evaporates. It should be noted that the second heat exchanger 154 may be a refrigerant-to-water heat exchanger. In this case, at the second heat exchanger 154, heat exchange is performed between the refrigerant and a heat medium such as water.

[0020] The first refrigerant distributor 152a distributes the refrigerant to the heat transfer tubes 13 (see Figs. 2 and 3) of the first heat exchanger 152. The outdoor fan 156 sends air for heat exchange to the first heat exchanger 152. The second refrigerant distributor 154a distributes the refrigerant to the heat transfer tubes (not illustrated) of the second heat exchanger 154. The indoor fan 157 sends air for heat exchange to the second heat exchanger 154.

[0021] The controller 160 performs an integrated control of the entire refrigeration cycle apparatus 200. Specifically, the controller 160 controls a drive frequency of the compressor 100 depending on a required cooling capacity or heating capacity. Furthermore, the controller 160 controls the opening degree of the expansion device 153 depending on the operation state and the operation mode, that is, which of operation modes is set. In addition, the controller 160 controls the flow switching device 151 depending on which of the operation modes is set.

[0022] The controller 160 uses information that is sent from each of temperature sensors (not illustrated) and each of pressure sensors (not illustrated) in response to an operation instruction given from a user, and controls

each of actuators, for example, the compressor 100, the expansion device 153, and the flow switching device 151.

[0023] As the controller 160, hardware such as a circuit device that can fulfill functions required for the controller 160 can be used. Alternatively, the controller 160 can be made up of an arithmetic device such as a microcomputer or a CPU and software that runs on the arithmetic device.

[0024] The controller 160 is dedicated hardware or a central processing unit (CPU) that executes a program stored in a memory (the CPU being also called a processing unit, an arithmetic device, a microprocessor, a microcomputer, or a processor). In the case where the controller 160 is dedicated hardware, the controller 160 corresponds to, for example, a single-component circuit, a composite circuit, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or a combination of these circuits. Functions that are fulfilled by the controller 160 may be fulfilled by respective hardware or single hardware. In the case where the controller 160 is a CPU, the functions that are fulfilled by the controller 160 are fulfilled by software, firmware, or a combination of software and firmware. The software and the firmware are written as programs and stored in a memory. To fulfill each of the functions of the controller 160, the CPU reads an associated program from the memory and executes the program. The memory is a nonvolatile or volatile semiconductor memory such as a RAM, a ROM, a flash memory, an EPROM, or an EEPROM. It should be noted that some of the functions of the controller 160 may be fulfilled by dedicated hardware or other some of the functions may be fulfilled by software or firmware.

[0025] It should be noted that Fig. 1 illustrates the case where at the first heat exchanger 152, the first refrigerant distributor 152a is provided, and at the second heat exchanger 154, the second refrigerant distributor 154a is provided; however, at only one of the first heat exchanger 152 and the second heat exchanger 154, the associated refrigerant distributor may be provided.

40 Operation of Refrigeration Cycle Apparatus 200

[0026] Next, an operation of the refrigeration cycle apparatus 200 will be described along with the flow of the refrigerant. The following description is made by referring to how the refrigeration cycle apparatus 200 is operated in the cooling operation in the case where a fluid to be subjected to heat exchange at the first heat exchanger 152 and the second heat exchanger 154 is air, for example. It should be noted that in Fig. 1, the flow of the refrigerant in the cooling operation is indicated by dashed arrows, and that of the refrigerant in the heating operation is indicated by solid arrows.

[0027] The compressor 100 is driven and discharges high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant (single phase) discharged from the compressor 100 flows into the first heat exchanger 152. At the first heat exchanger 152, heat exchange is performed between the

high-temperature and high-pressure gas refrigerant and air supplied by the outdoor fan 156, and the high-temperature and high-pressure gas refrigerant is condensed to change into high-pressure liquid refrigerant (single phase).

[0028] The high-pressure liquid refrigerant sent from the first heat exchanger 152 is changed by the expansion device 153 into two-phase gas-liquid refrigerant in which low-pressure gas refrigerant and liquid refrigerant are present. The two-phase gas-liquid refrigerant is collected by the second refrigerant distributor 154a, and the collected two-phase gas-liquid refrigerant flows into the second heat exchanger 154. At the second heat exchanger 154, the two-phase gas-liquid refrigerant that has flowed thereinto after being distributed by the second refrigerant distributor 154a exchanges heat with air supplied by the indoor fan 157, and as a result, liquid refrigerant of the two-phase gas-liquid refrigerant evaporates to change into low-pressure single-phase gas refrigerant. The low-pressure gas refrigerant sent from the second heat exchanger 154 flows into the compressor 100 through the accumulator 300, and is compressed by the compressor 100 to change into high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant is re-discharged from the compressor 100. This cycle is then repeatedly carried out.

[0029] In the heating operation, in the refrigeration cycle apparatus 200, the flow of the refrigerant is switched by the flow switching device 151 to a flow indicated by solid arrows in Fig. 1.

[0030] The refrigerant on the discharge side of the compressor 100 may be made to flow only in a single direction without providing the flow switching device 151 on the discharge side of the compressor 100.

[0031] In the case where the refrigeration cycle apparatus 200 is a dedicated refrigerant cycle apparatus for the cooling operation or the heating operation, and it is not necessary to switch the flow direction of the refrigerant, the flow switching device 151 does not need to be provided.

[0032] The refrigeration cycle apparatus 200 can be applied not only as the air-conditioning apparatus, but also as a water heater, a refrigerating machine, an air-conditioning and water-heating complex machine, etc.

First Heat Exchanger 152

[0033] Fig. 2 is a schematic sectional view of the first heat exchanger 152 in the refrigeration cycle apparatus 200 according to Embodiment 1 as viewed from the front. Fig. 3 is a schematic sectional view of the first heat exchanger 152 in the refrigeration cycle apparatus 200 according to Embodiment 1 as viewed side-on.

[0034] Although Figs. 2 and 3 illustrates the first heat exchanger 152, the second heat exchanger 154 also has the same configuration as the first heat exchanger 152. Furthermore, the second refrigerant distributor 154a of the second heat exchanger 154 has the same configu-

ration as the first refrigerant distributor 152a of the first heat exchanger 152. In Fig. 2, the flow of the refrigerant in the case where the first heat exchanger 152 is used as an evaporator is indicated by an outlined arrow.

[0035] As illustrated in Figs. 2 and 3, the first heat exchanger 152 includes a plurality of heat transfer tubes 13. A gas header 14 and the first refrigerant distributor 152a are provided to extend in the horizontal direction. The heat transfer tubes 13 are arranged apart from each other in the horizontal direction; and one of ends of each of the heat transfer tubes 13 is inserted into an outer tube 11 of the first refrigerant distributor 152a, and the other end of the heat transfer tube 13 is inserted into the gas header 14. Fins (not illustrated) are attached to the heat transfer tubes 13 such that between any adjacent two of the heat transfer tubes 13, an associated one of the fins is located. The fins transfer heat to the heat transfer tubes 13. In the gas header 14, an outflow member 14a is provided in such a manner as to communicate with the inside of the gas header 14. The outflow member 14a is connected to the pipe 155a connected to the compressor 100.

First Refrigerant Distributor 152a

[0036] As illustrated in Figs. 2 and 3, the first refrigerant distributor 152a has a double-tube structure in which an inner tube 12 and the outer tube 11 are provided. To the outer tube 11, the heat transfer tubes 13 are connected such that the heat transfer tubes 13 are arranged in an extending direction of the outer tube 11. The two-phase gas-liquid refrigerant that flows between the inner tube 12 and the outer tube 11 is distributed to the heat transfer tubes 13.

[0037] The first refrigerant distributor 152a is connected to an inlet side of the first heat exchanger 152 that is an inlet side for two-phase gas-liquid refrigerant that flows in the case where the first heat exchanger 152 serves as an evaporator.

[0038] The inner tube 12 is held such that the extending direction of the inner tube 12 is the horizontal direction. The two-phase gas-liquid refrigerant flows into one end of the inner tube 12. A cap 12b is provided at a most downstream part of the inner tube 12 in the flow of the refrigerant in the case where the first heat exchanger 152 serves as an evaporator. The pipe 155a connected to the expansion device 153 of a refrigeration cycle circuit is connected to a most upstream part of the inner tube 12 in the flow of the refrigerant in the inner tube 12 in the case where the first heat exchanger 152 serves as an evaporator.

[0039] As illustrated in Figs. 2 and 3, dispersion holes 12a that are called orifice holes and that allow the refrigerant to flow to the outer tube 11 are formed in lower portion of the inner tube 12 in the direction of gravity such that dispersion holes 12a are arranged apart from each other in the extending direction of the inner tube 12. The dispersion holes 12a each have a diameter of 0.5 mm to

4 mm. The dispersion holes 12a may be formed in the lower portion of the inner tube 12 in the direction of gravity and at positions that are located just below spaces between the heat transfer tubes 13. By virtue of this configuration, a refrigerant distributing function of the first refrigerant distributor 152a can be improved, as compared with the case where the dispersion holes 12a are formed in portions of the inner tube 12 that are located just below the heat transfer tubes 13. In addition, the inner tube 12 has an inflow portion 12c into which the refrigerant flows.

[0040] Fig. 4 illustrates a cross section of the inner tube 12 of the first refrigerant distributor 152a in the refrigeration cycle apparatus 200 according to Embodiment 1. The cross section is a cross section perpendicular to the extending direction of the inner tube 12 of the first refrigerant distributor 152a. Fig. 5 is an explanatory view for the extending direction of projections 31 formed on an inner wall 12d of the inner tube 12 in the first refrigerant distributor 152a in Embodiment 1.

[0041] As illustrated in Fig. 4, the projections 31 are arranged on the inner wall 12d of the inner tube 12 in a circumferential direction thereof. As illustrated in Fig. 5, the projections 31 are provided to extend in parallel with each other in the extending direction of the inner tube 12.

[0042] The cross section of each of the projections 31 is not limited to such a triangle as illustrated in Fig. 4, and may be a trapezoid, a rectangle, a semi-circle, or another shape.

[0043] In such a manner, because of provision of the projections 31, liquid refrigerant 32 of the two-phase gas-liquid refrigerant is retained between the projections 31. As a result, the liquid refrigerant 32 is kept uniform in the circumferential direction of the inner tube 12. In a central region of the inner tube 12, gas refrigerant 33 of the two-phase gas-liquid refrigerant flows. Therefore, the two-phase gas-liquid refrigerant uniformly flows from the inner tube 12 to the outer tube 11 through the dispersion holes 12a, and is uniformly distributed to the heat transfer tubes 13.

Operation of First Heat Exchanger 152

[0044] Next, it will be described how the first heat exchanger 152 is operated in the heating operation, in which the first heat exchanger 152 serves as an evaporator. It should be noted that although the following description is made with respect to the case where the first heat exchanger 152 serves as an evaporator, the operation of the second heat exchanger 154 in the case where the second heat exchanger 154 serves as an evaporator is the same as that of the first heat exchanger 152 in the case where the first heat exchanger 152 serves as an evaporator. Furthermore, in the case where the first heat exchanger 152 serves as a condenser, the refrigerant flows in the opposite direction to the flow direction of the refrigerant in the case where the first heat exchanger 152 serves as an evaporator.

[0045] Referring to Fig. 2, the two-phase gas-liquid refrigerant that has flowed into the inflow portion 12c of the inner tube 12 flows in the inner tube 12 and are dispersed from the dispersion holes 12a of the inner tube 12 into the outer tube 11. The two-phase gas-liquid refrigerant dispersed into the outer tube 11 flows into the heat transfer tubes 13, and exchanges heat with air while being flowing through the heat transfer tubes 13, thereby changing into low-pressure gas refrigerant. The low-pressure gas refrigerant flows into the gas header 14. The low-pressure gas refrigerant that has flowed into the gas header 14 is output from the outflow member 14a.

[0046] As illustrated in Fig. 4, the liquid refrigerant 32 of the two-phase gas-liquid refrigerant that has flowed into the inflow portion 12c of the inner tube 12 flows between the projections 31. The liquid refrigerant 32 that flows between the projections 31 is kept uniform in the circumferential direction of the inner tube 12. In the central region of the inner tube 12, the gas refrigerant 33 of the two-phase gas-liquid refrigerant flows.

[0047] The two-phase gas-liquid refrigerant that flows in the inner tube 12 passes through the dispersion holes 12a and flows out into the outer tube 11. The two-phase gas-liquid refrigerant that has flowed into the outer tube 11 is distributed to the heat transfer tubes 13. The liquid refrigerant 32 is kept uniform in the circumferential direction between the projections 31 which extend in the extending direction of the inner tube 12. Therefore, the two-phase gas-liquid refrigerant passes through the dispersion holes 12a, uniformly flows out from the inner tube 12 into the outer tube 11 from an upstream side to a downstream side in the flow direction of the refrigerant, and is uniformly distributed to the heat transfer tubes 13.

[0048] The two-phase gas-liquid refrigerant distributed to the heat transfer tubes 13 exchanges heat with air to change into gas refrigerant, and the gas refrigerant is output from the outflow member 14a of the gas header 14 through the gas header 14. The gas refrigerant output from the outflow member 14a of the gas header 14 passes through the pipe 155a, and returns to the compressor 100 through the flow switching device 151 and the accumulator 300.

Modification

[0049] The projections 31 may be formed to extend in a direction inclined to the extending direction of the inner tube 12. Fig. 6 is an explanatory view for the extending direction of projections 31 of a modification that are formed on the inner wall 12d of the inner tube 12 in the first refrigerant distributor 152a according to Embodiment 1. Fig. 6 illustrates two of the projections 31, that is, a projection 31a and a projection 31b, as representatives of the projections 31. As illustrated in Fig. 6, the projection 31a and the projection 31b extend in the direction inclined to the extending direction of the inner tube 12.

[0050] In the first refrigerant distributor 152a and the second refrigerant distributor 154a in the refrigeration cy-

cle apparatus 200 according to Embodiment 1, of the two-phase gas-refrigerant that flows in the inner tube 12, liquid refrigerant is kept uniform in the circumferential direction between the projections 31a and 31b formed on the inner wall 12d of the inner tube 12. Thus, the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes 12a and is uniformly distributed to the heat transfer tubes 13, regardless of the flow rate of the refrigerant. Furthermore, since the projections 31 are provided in the first refrigerant distributor 152a and the second refrigerant distributor 154a, the two-phase gas-liquid refrigerant is uniformly distributed to the heat transfer tubes 13 through the dispersion holes 12a regardless which of the heating operation and the cooling operation is performed.

Embodiment 2

[0051] Next, a refrigeration cycle apparatus 200 according to Embodiment 2 will be described. The configuration of a refrigerant circuit in Embodiment 2 is the same as that in the refrigerant circuit in the refrigeration cycle apparatus 200 according Embodiment 1, but the configuration of each of the first refrigerant distributor 152a and the second refrigerant distributor 154a is different from that in Embodiment 1.

[0052] Fig. 7 illustrates a cross section of the inner tube 12 of the first refrigerant distributor 152a in the refrigeration cycle apparatus 200 according to Embodiment 2. The cross section of the inner tube 12 in the first refrigerant distributor 152a is a cross section perpendicular to the extending direction of the inner tube 12.

[0053] As illustrated in Fig. 7, the projections 31 are arranged in the circumferential direction on the inner wall 12d of the inner tube 12. The projections 31 are provided to extend in parallel with each other in the extending direction of the inner tube 12.

[0054] Fig. 8 is an explanatory view for the extending direction of the projections 31 formed on the inner wall 12d of the inner tube 12 in the first refrigerant distributor 152a according to Embodiment 2. Fig. 8 illustrates two of the projections 31, that is, a projection 31c and a projection 31d, as representatives of the projections 31. Referring to Fig. 8, the projection 31c and the projection 31d are provided to helically extend in parallel with each other in the extending direction of the inner tube 12. The other projections 31, as well as the projections 31c and 31d, are also provided to helically extend in parallel with each other in the extending direction of the inner tube 12. It should be noted that although Figs. 7 and 8 illustrate the first refrigerant distributor 152a, the second refrigerant distributor 154a also has the same configuration as the first refrigerant distributor 152a.

[0055] Because of provision of the above configuration, the liquid refrigerant of the two-phase gas-liquid refrigerant that flows in the inner tube 12 is kept uniform between the projections 31 formed on the inner wall 12d of the inner tube 12. Furthermore, since the projections

31 are formed to extend helically, a force that keeps the refrigerant uniform in the circumferential direction of the inner tube 12 is enhanced by a centrifugal force that is generated by the liquid refrigerant when the refrigerant is flowing in the inner tube 12. Thus, the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes 12a and is uniformly distributed to the heat transfer tubes 13, regardless of the flow rate of the refrigerant.

[0056] In the first refrigerant distributor 152a of the refrigeration cycle apparatus 200 according to Embodiment 2, of the two-phase gas-liquid refrigerant which flows in the inner tube 12, the projections 31 are helically formed on the inner wall 12d of the inner tube 12. Thus, a centrifugal force is generated by the liquid refrigerant 32 to act to keep the liquid refrigerant 32 uniform in the circumferential direction between the projections 31c and 31d. As a result, the two-phase gas-liquid refrigerant is uniformly dispersed from the dispersion holes 12a and is uniformly distributed to the heat transfer tubes 13 regardless of the amount of the refrigerant.

Embodiment 3

[0057] A refrigeration cycle apparatus 200 according to Embodiment 3 will be described. The configuration of a refrigerant circuit according to Embodiment 3 is the same as that of the refrigerant circuit in the refrigeration cycle apparatus 200 according to Embodiment 1 which is provided as illustrated in Fig. 1, but the configuration of each of the first refrigerant distributor 152a and the second refrigerant distributor 154a is different from that in Embodiment 1.

[0058] Fig. 9 indicates the height of each of the projections 31 formed on the inner wall 12d of the inner tube 12 in the first refrigerant distributor 152a according to Embodiment 3. In Fig. 9, an outlined arrow indicates the flow of the two-phase gas-liquid refrigerant in the case where the first refrigerant distributor 152a serves as an evaporator. As illustrated in Fig. 9, the height h_2 of part of the projection 31 from the inner wall 12d of the inner tube 12 that is located on the downstream side in the flow of the two-phase gas-liquid refrigerant is greater than the height h_1 of part of the projection 31 from the inner wall 12d of the inner tube 12 that is located on the upstream side in the flow of the two-phase gas-liquid refrigerant. It should be noted that although Fig. 9 illustrates the above configuration in the first refrigerant distributor 152a, the second refrigerant distributor 154a also has the same configuration as the first refrigerant distributor 152a.

[0059] In the case where the first heat exchanger 152 serves as an evaporator, the two-phase gas-liquid refrigerant continuously flows to the outer tube 11 through the dispersion holes 12a. As a result, the flow rate of the liquid refrigerant 32 that flows in the inner tube 12 is lower on the downstream side of the two-phase gas-liquid refrigerant than on the upstream side of the two-phase gas-liquid refrigerant. Accordingly, a force by which the liquid refrigerant 32 is kept uniform on the inner wall 12d of the

inner tube 12 gradually lowers in a direction from the upstream side of the two-phase gas-liquid refrigerant toward the downstream side thereof.

[0060] In the first refrigerant distributor 152a according to Embodiment 3, the height h2 of part of the projection 31 from the inner wall 12d of the inner tube 12 that is located on the downstream side of the two-phase gas-liquid refrigerant is set greater than the height h1 of part of the projection 31 from the inner wall 12d of the inner tube 12 that is located on the upstream side of the two-phase gas-liquid refrigerant.

[0061] By forming each projection 31 in the above manner, the effect of the surface tension of the liquid refrigerant 32 that flows in the inner tube 12 is increased, and the force by which the liquid refrigerant 32 is kept uniform on the inner wall 12d is increased.

[0062] It should be noted that although Fig. 9 illustrates the case where the height of the projection 31 gradually increases from the upstream side of the two-phase gas-liquid refrigerant toward the downstream side thereof, the height of the projection 31 may increase in a stepwise manner from the upstream side of the two-phase gas-liquid refrigerant toward the downstream side thereof.

[0063] In the first refrigerant distributor 152a of the refrigeration cycle apparatus 200 according to Embodiment 3, the height h2 of the part of the projection 31 which is located on the downstream side is set greater than the height h1 of the part of the projection 31 which is located on the upstream side. Thus, it is possible to increase the force by which the liquid refrigerant 32 is kept uniform on the inner wall 12d. Therefore in the first refrigerant distributor 152a of the refrigeration cycle apparatus 200 according to Embodiment 3, the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes 12a and is uniformly distributed to the heat transfer tubes 13.

Embodiment 4

[0064] A refrigeration cycle apparatus 200 according to Embodiment 4 will be described. The configuration of a refrigerant circuit according to Embodiment 4 is the same as that in the refrigerant circuit in the refrigeration cycle apparatus 200 according to Embodiment 1 which is provided as illustrated in Fig. 1. In Embodiment 1, the dispersion holes 12a are formed in the lower portion of the inner tube 12 in the direction of gravity, and in Embodiment 4, the positions of the dispersion holes 12a of the inner tube 12 in the first refrigerant distributor 152a are different from those in Embodiment 1. It should be noted that the positions of the dispersion holes 12a of the inner tube 12 in the second refrigerant distributor 154a are the same as those in the first refrigerant distributor 152a.

[0065] Fig. 10 is a cross-section view that is perpendicular to the extending direction of the inner tube 12 and that indicates the positions of the dispersion holes 12a of the inner tube 12 in the first refrigerant distributor 152a

according to Embodiment 4.

[0066] An angle φ [deg] from a vertical line that extends from the center of the inner tube 12 to a line that extends from the center of the inner tube 12 to each of the dispersion holes 12a satisfies the following formulas (1) and (2):

$$\theta - 20 < \varphi < 180 \quad \dots (1)$$

$$\alpha = 1 - \theta / 180 + \sin\theta \cos\theta / \pi \quad \dots (2)$$

where θ is an estimated liquid level angle [deg], and α is a void fraction. The formulas (1) and (2) are obtained as the area of a sector - the area of a triangle by a trigonometric function from a liquid cross section calculated from the void fraction α .

[0067] In such a manner, the dispersion holes 12a are provided at the angle φ that satisfies the above formulas (1) and (2), and are thus located between a position slightly lower than a gas-liquid interface 34 in a stratified flow calculated from the void fraction and a position that is rotated from the above slightly lower position through 180°. This is because the liquid level of the gas-liquid interface 34 is located at an upper position by the surface tension than in the case where the gas-liquid interface is a gas-liquid interface in a stratified flow.

[0068] Therefore, in the first refrigerant distributor 152a and the second refrigerant distributor 154a in the refrigeration cycle apparatus 200 according to Embodiment 4, also, when the liquid refrigerant 32 comes from an annular flow close to the stratified flow, the two-phase gas-liquid refrigerant flows out from the gas-liquid interface 34 to the dispersion holes 12a. Thus, the refrigerant can be uniformly distributed to the heat transfer tubes 13.

Embodiment 5

[0069] A refrigeration cycle apparatus 200 according to Embodiment 5 will be described. The configuration of a refrigerant circuit according to Embodiment 5 is the same as that in the refrigerant circuit in the refrigeration cycle apparatus 200 according to Embodiment 1, which is provided as illustrated in Fig. 1. Embodiment 5 is different from Embodiment 1 in the positions of the projections 31 provided on the inner wall 12d of the inner tube 12 in the first refrigerant distributor 152a. It should be noted that the positions of the projections 31 in the second refrigerant distributor 154a are the same as the positions of the projections 31 in the first refrigerant distributor 152a.

[0070] Fig. 11 is a schematic sectional view of the first heat exchanger 152 in the refrigeration cycle apparatus 200 according to Embodiment 5 as viewed from the front. Fig. 11 illustrates only some of the projections formed in the circumferential direction on the inner wall 12d of the inner tube 12, as a matter of convenience for illustration.

It should be noted that descriptions concerning points on which the configuration as illustrated in Fig. 11 is the same as the configuration as illustrated in Fig. 2 will be omitted, and only points on which the configuration of Fig. 11 is different from that of Fig. 2 will be described.

[0071] Although Fig. 11 illustrates the first heat exchanger 152, the second heat exchanger 154 also has the same configuration as the first heat exchanger 152. In Fig. 11, the flow of the refrigerant is indicated by an outlined arrow in the case where the first heat exchanger 152 serves as an evaporator.

[0072] As illustrated in Fig. 11, the inner tube 12 has a projection formation portion 41 and a smooth portion 42. The projection formation portion 41 is located on the upstream side in the flow of the two-phase gas-liquid refrigerant and is located upstream of the most upstream one of the dispersion holes 12a. The projections 31 are formed on the inner wall 12d of the inflow portion 12c of part of the inner tube 12 that is located in the projection formation portion 41. The smooth portion 42 is located downward of the projection formation portion 41 in the flow of the two-phase gas-liquid refrigerant. The inner wall 12d of part of the inner tube 12 that is located in the smooth portion 42 is smooth.

[0073] In the above configuration, since the projections 31 are formed on the upstream side in the flow of the two-phase gas-liquid refrigerant, on the upstream side, the liquid refrigerant is uniformly distributed in the circumferential direction of the inner tube 12. In addition, also, when the liquid refrigerant flows from the upstream side to the downstream side, the state of the liquid refrigerant distributed in the circumferential direction is maintained, and the liquid refrigerant also flows along the inner wall 12d in the smooth portion 42.

[0074] Therefore, in the first refrigerant distributor 152a according to Embodiment 5, since the projections 31 are formed on the inner wall 12d of the inner tube 12 on the upstream side in the flow of the two-phase gas-liquid refrigerant, also in the smooth portion 42 located on the downstream side, the liquid refrigerant flows along the inner wall 12d of the inner tube 12. Thus, even in the case where the projections 31 are formed only on the projection formation portion 41 located on the upstream side, in the smooth portion 42 located on the downstream side, the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes 12a and is uniformly distributed to the heat transfer tubes 13.

Embodiment 6

[0075] A refrigeration cycle apparatus 200 according to Embodiment 6 will be described. The configuration of a refrigerant circuit according to Embodiment 6 is the same as that of the refrigerant circuit in the refrigeration cycle apparatus 200 according to Embodiment 1 which is provided as illustrated in Fig. 1. In Embodiment 6, the positions of the projections 31 provided on the inner wall 12d of the inner tube 12 in the first refrigerant distributor

152a are different from those of the projections 31 in Embodiment 5. It should be noted that the positions of the projections 31 in the second refrigerant distributor 154a are the same as those of the projections 31 in the first refrigerant distributor 152a.

[0076] Fig. 12 is a schematic sectional view of the first heat exchanger 152 of the refrigeration cycle apparatus 200 according to Embodiment 6 as viewed from the front. Fig. 12 illustrates only some of the projections 31 formed in the circumferential direction on the inner wall 12d of the inner tube 12 as a matter of convenience for illustration. It should be noted that descriptions concerning points on which the configuration as illustrated in Fig. 12 is the same as that in Fig. 2 will be omitted, and only points on which the configuration of Fig. 12 is different from that of Fig. 2 will be described.

[0077] Although Fig. 12 also illustrates the first heat exchanger 152, the second heat exchanger 154 has the same configuration as the first heat exchanger 152. In Fig. 12, the flow of the refrigerant in the case where the first heat exchanger 152 serves as an evaporator is indicated by an outlined arrow.

[0078] As illustrated in Fig. 12, the inner tube 12 has the smooth portion 42 and the projection formation portion 41. In the smooth portion 42, the inner wall 12d of the inner tube 12 is smooth, and the smooth portion 42 is located on the upstream side in the flow of the two-phase gas-liquid refrigerant. The projection formation portion 41 is located downstream of the smooth portion 42 in the flow of the two-phase gas-liquid refrigerant, and projections 31 are formed in the projection formation portion 41. To be more specific, the projection formation portion 41 is located downstream of a region in which the heat transfer tubes 13 are located. The projections 31 formed on the projection formation portion 41 are located downstream of the most downstream one of the dispersion holes 12a, and formed on the inner wall 12d of part of the inner tube 12 that is located downstream of the region in which the heat transfer tubes 13 are located.

[0079] In the above configuration, since the smooth portion 42 is located on the upstream side in the flow of the two-phase gas-liquid refrigerant, the two-phase gas-liquid refrigerant flows in a state in which a pressure loss of a region in the inner tube 12 where the flow rate of the two-phase gas-liquid refrigerant is high is reduced. Also, on the downstream side, in the projection formation portion 41, projections 31 are provided. Thus, the liquid refrigerant flows along the inner wall 12d of the inner tube 12, and even if the flow rate of the two-phase gas-liquid refrigerant is reduced, occurrence of separation between air refrigerant and liquid refrigerant is reduced.

[0080] Therefore, in the first refrigerant distributor 152a according to Embodiment 6, since the projections 31 are provided on the inner wall 12d of part of the inner tube 12 that is located on the downstream side in the flow of the two-phase gas-liquid refrigerant, the liquid refrigerant flows along the inner wall 12d of the inner tube 12. Thus, even in the case where the projections 31 are formed

only in the projection formation portion 41 located on the downstream side, and the flow rate of the two-phase gas-liquid refrigerant is reduced, occurrence of separation between air refrigerant and liquid refrigerant is reduced, and the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes 12a which are located around a downstream end portion where the projections 31 are located, and are uniformly distributed to the heat transfer tubes 13.

[0081] The embodiments are described above as examples, and do not intend to define the claims. The embodiments can be put to practical use in various manners, and various modifications, replacement, and omissions can be made without departing from the gist of the embodiments. The embodiments and modifications thereof are covered within the range and gist of the embodiments.

Reference Signs List

[0082] 11: outer tube, 12: inner tube, 12a: dispersion hole, 12b: cap, 12c: inflow portion, 12d: inner wall, 13: heat transfer tube, 14: gas header, 14a: outflow portion, 31, 31a-31d: projection, 32: liquid refrigerant, 33: gas refrigerant, 34: gas-liquid interface, 41: projection formation portion, 42: smooth portion, 100: compressor, 101: outdoor unit, 102: indoor unit, 151: flow switching device, 152: first heat exchanger, 152a: first refrigerant distributor, 153: expansion device, 154: second heat exchanger, 154a: second refrigerant distributor, 155a, 155b: pipe, 156: outdoor fan, 157: indoor fan, 160: controller, 200: refrigeration cycle apparatus, 300: accumulator, h1: height of projection on upstream side in flow of two-phase gas-liquid refrigerant, h2: height of projection on downstream side in flow of two-phase gas-liquid refrigerant, θ : estimated liquid level angle, α : void fraction, φ : angle of dispersion hole

Claims

1. A refrigerant distributor comprising:

an outer tube to which a heat transfer tube is connected; and
an inner tube accommodated in the outer tube and having a dispersion hole that allows refrigerant to flow to the outer tube,
wherein
the inner tube has an inner wall on which a projection is formed to extend in an extending direction of the inner tube, and
a plurality of projections including the projection are formed on the inner wall of the inner tube and arranged in a circumferential direction of the inner tube.

2. The refrigerant distributor of claim 1, wherein the pro-

jection is formed to helically extend in the extending direction of the inner tube.

3. The refrigerant distributor of claim 1, wherein the projection is formed to extend in a direction inclined to the extending direction of the inner tube.

4. The refrigerant distributor of any one of claims 1 to 3, wherein part of the projection that is located on a downstream side in a flow of two-phase gas-liquid refrigerant has a greater height than a height of part of the projection that is located on an upstream side in the flow of the two-phase gas-liquid refrigerant.

5. The refrigerant distributor of any one of claims 1 to 4, wherein an angle φ from a vertical line that extends from a center of the inner tube to a line that extends to the dispersion hole is set to satisfy the following formulas (1) and (2):

$$\theta - 20 < \varphi < 180 \quad \dots (1)$$

$$\alpha = 1 - \theta / 180 + \sin \theta \cos \theta / \pi \quad \dots (2)$$

where θ is an estimated liquid level angle, and α is a void fraction.

6. The refrigerant distributor of any one of claims 1 to 5, wherein the inner tube is provided on an upstream side in a flow of two-phase gas-liquid refrigerant, and has a projection formation portion in which the projection is formed and a smooth portion which is located downstream of the projection formation portion in the flow of the two-phase gas-liquid refrigerant and in which the inner wall of the inner tube is smooth.

7. The refrigerant distributor of any one of claims 1 to 5, wherein the inner tube is provided on an upstream side in a flow of two-phase gas-liquid refrigerant, and has a smooth portion in which the inner wall of the inner tube is smooth and a projection formation portion which is located downward of the smooth portion in the flow of the two-phase gas-liquid refrigerant and in which the projection is provided.

8. A heat exchanger comprising the refrigerant distributor of any one of claims 1 to 7.

9. An air-conditioning apparatus comprising the heat exchanger of claim 8.

FIG. 1

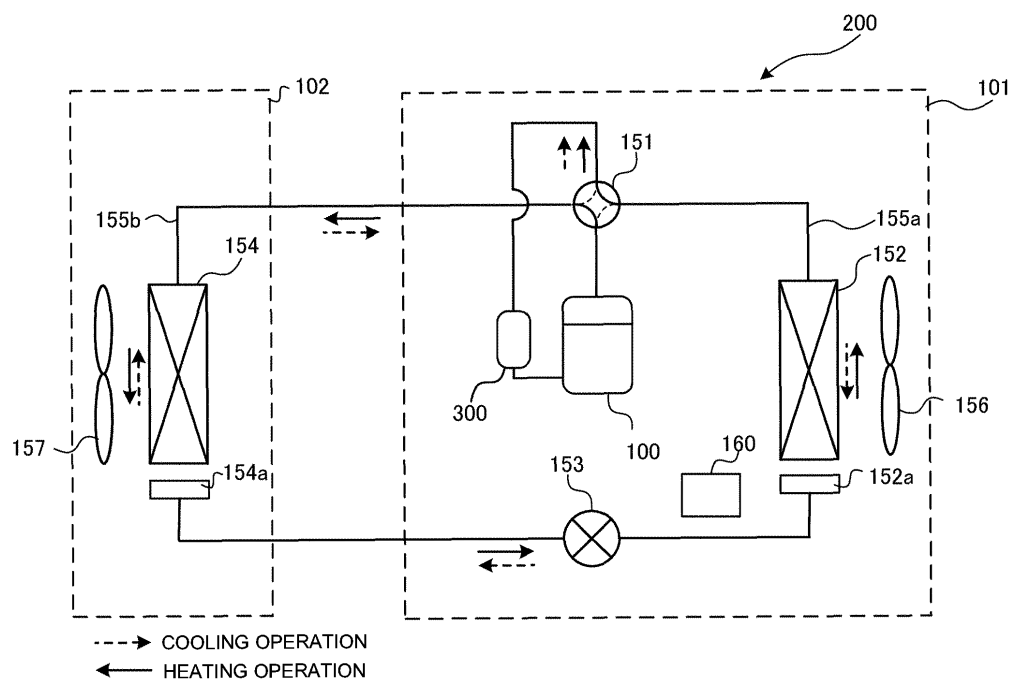


FIG. 2

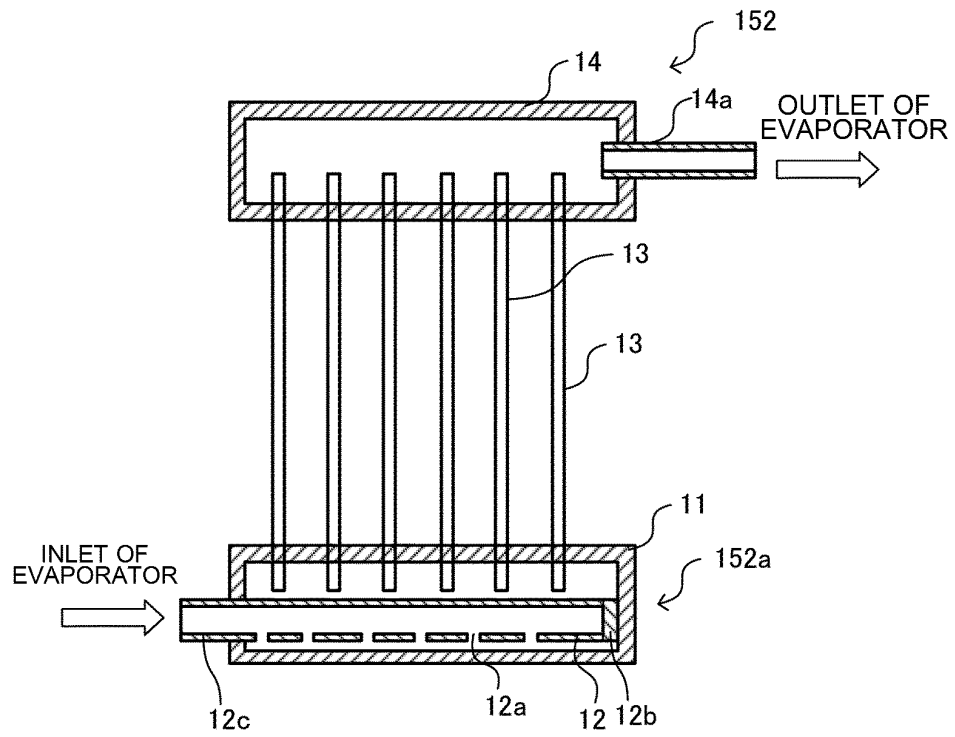


FIG. 3

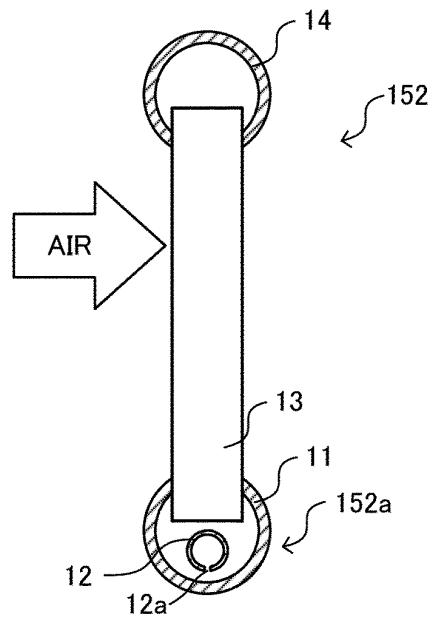


FIG. 4

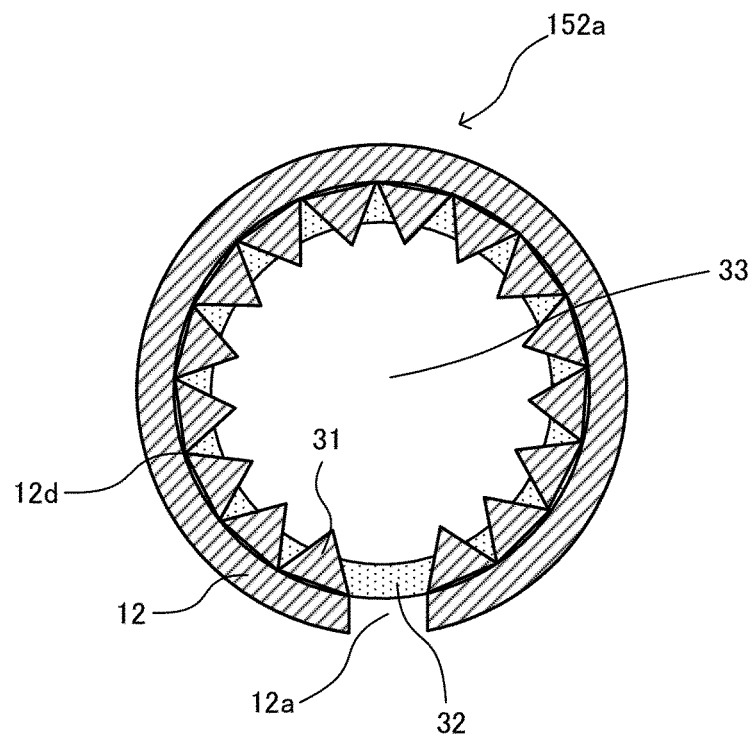


FIG. 5

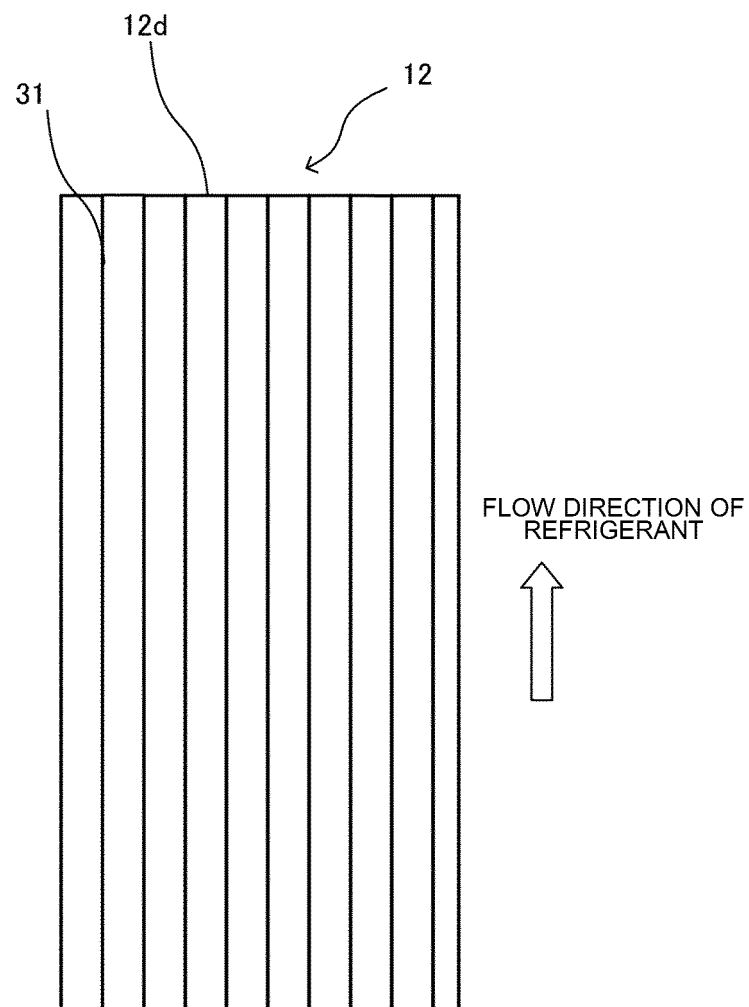


FIG. 6

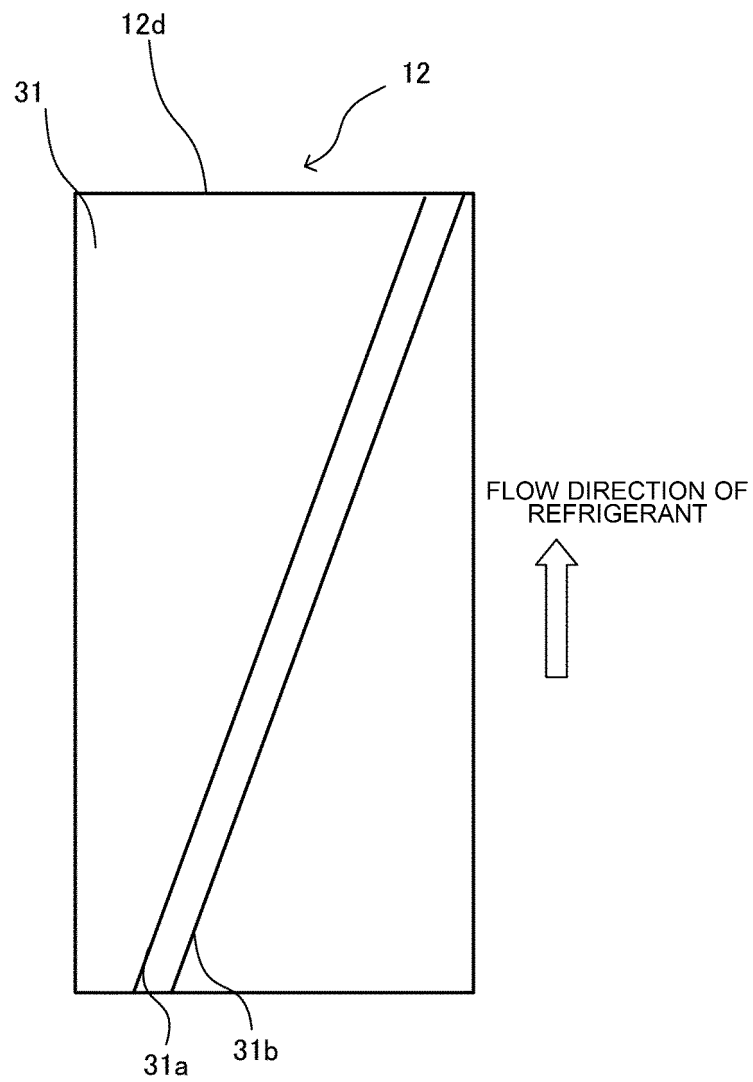


FIG. 7

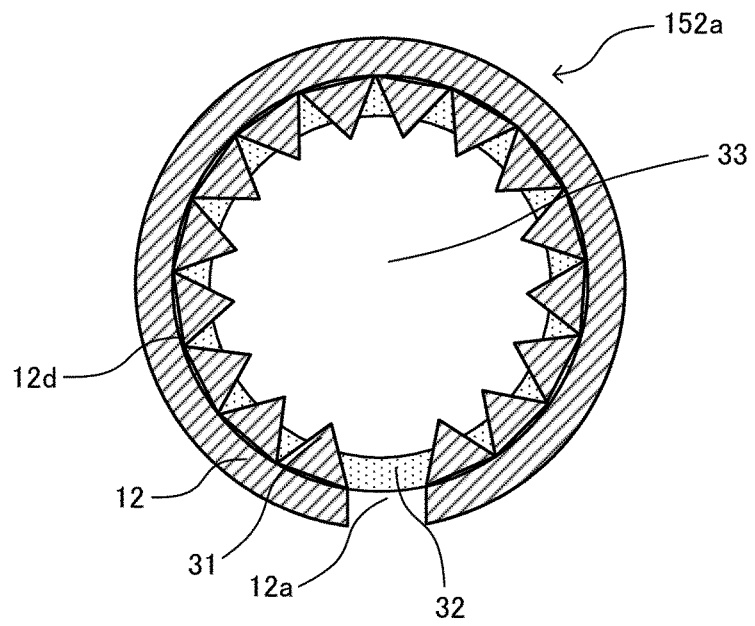


FIG. 8

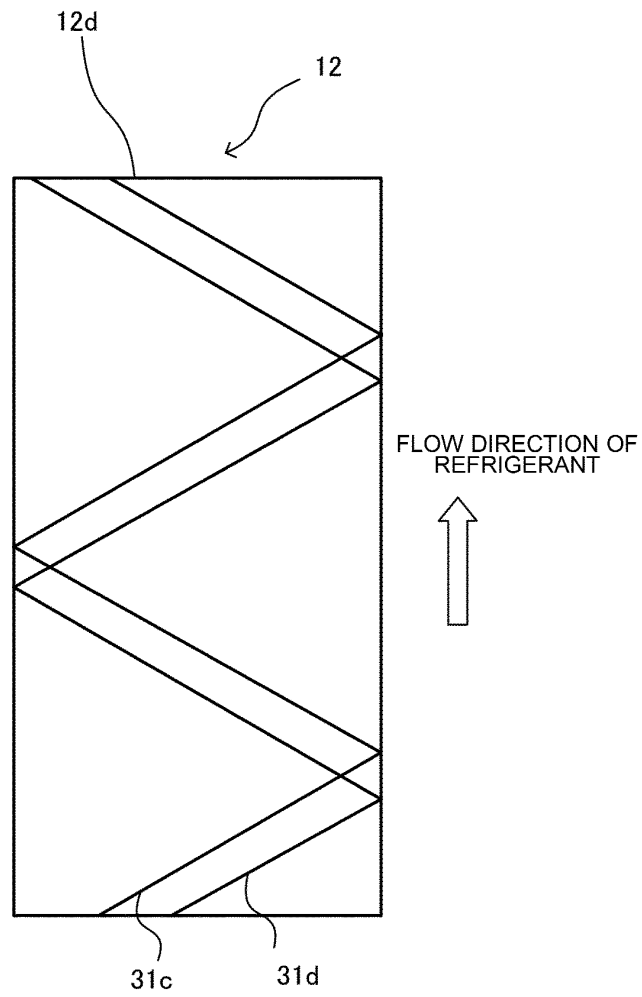


FIG. 9

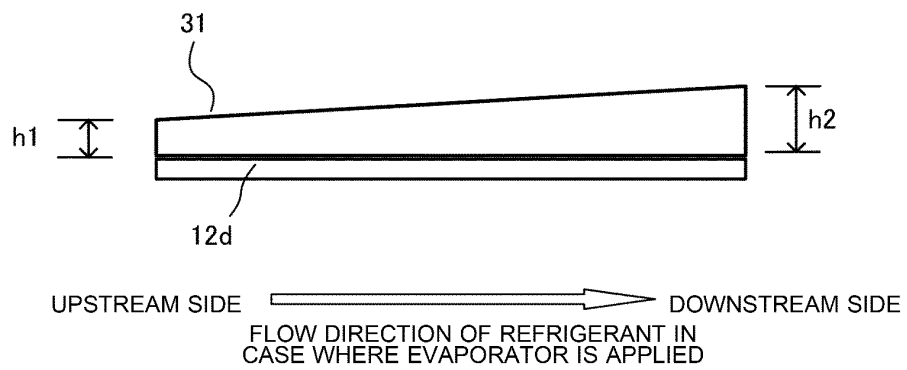


FIG. 10

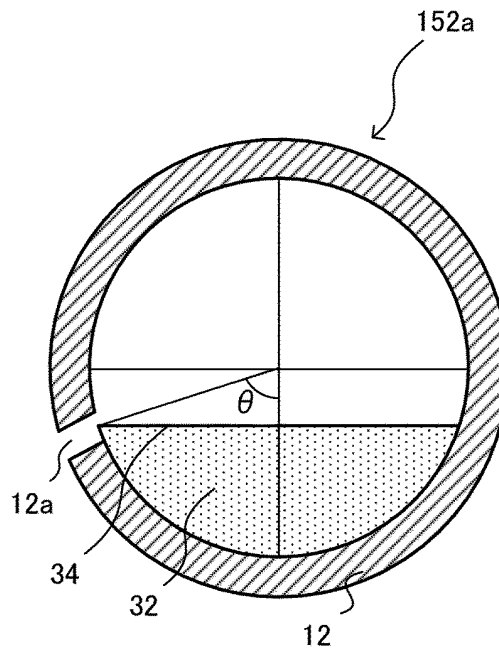


FIG. 11

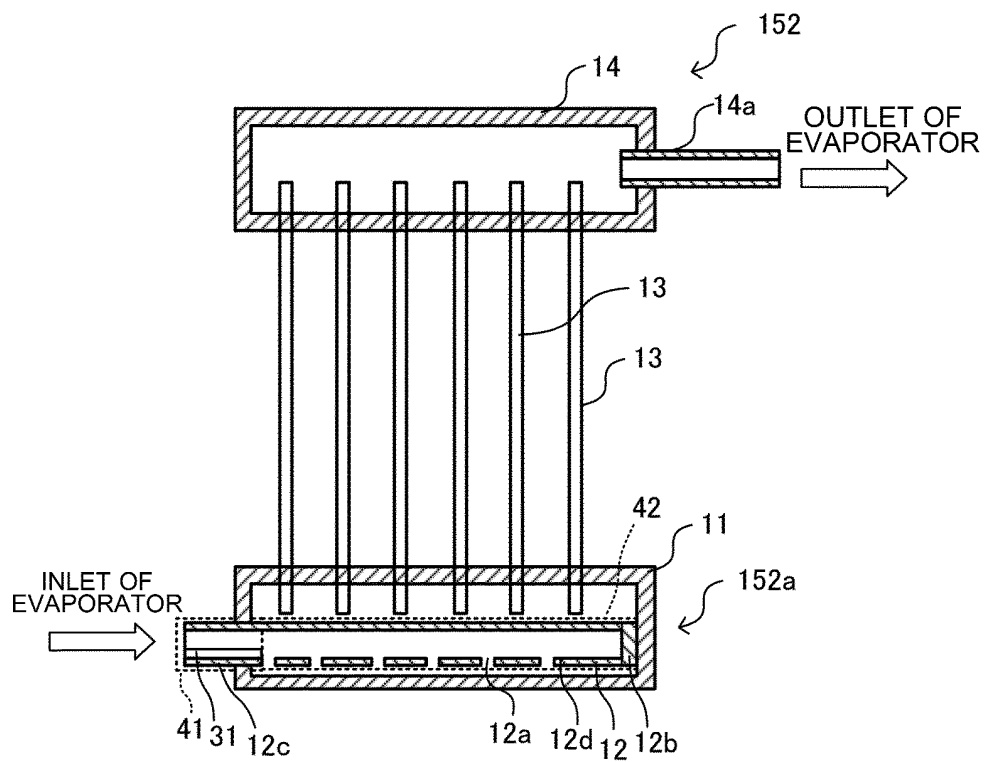
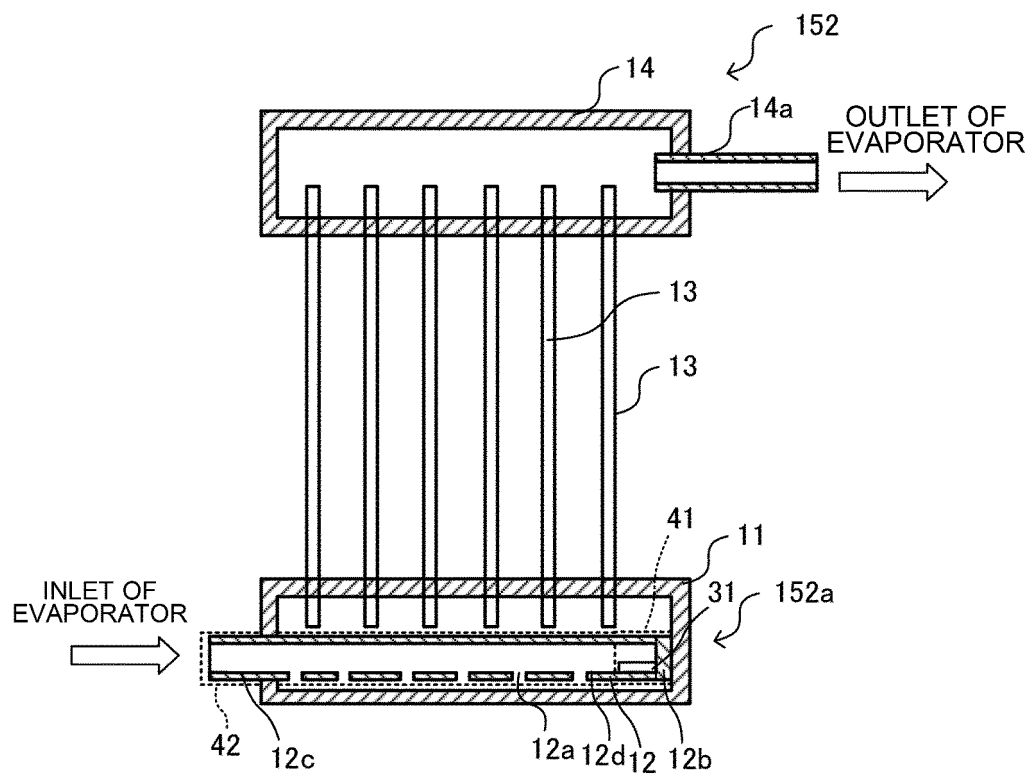


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/037091

A. CLASSIFICATION OF SUBJECT MATTER <i>F25B 41/42</i> (2021.01)i FI: F25B41/42 According to International Patent Classification (IPC) or to both national classification and IPC																														
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Minimum documentation searched (classification system followed by classification symbols) F25B41/42																														
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 1971-2021 Registered utility model specifications of Japan 1996-2021 Published registered utility model applications of Japan 1994-2021 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)																														
C. DOCUMENTS CONSIDERED TO BE RELEVANT																														
<table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>JP 2012-2475 A (MITSUBISHI ELECTRIC CORP.) 05 January 2012 (2012-01-05) paragraphs [0001], [0012]-[0030], fig. 1-8</td> <td>1-3, 8-9</td> </tr> <tr> <td>Y</td> <td></td> <td>2-4</td> </tr> <tr> <td>A</td> <td></td> <td>5-7</td> </tr> <tr> <td>X</td> <td>JP 2010-139196 A (SHARP CORP.) 24 June 2010 (2010-06-24) paragraphs [0030]-[0049], fig. 1-7</td> <td>1, 8-9</td> </tr> <tr> <td>Y</td> <td></td> <td>2-4</td> </tr> <tr> <td>A</td> <td></td> <td>5-7</td> </tr> <tr> <td>Y</td> <td>JP 2011-17505 A (MITSUBISHI ELECTRIC CORP.) 27 January 2011 (2011-01-27) paragraphs [0014]-[0016], fig. 4</td> <td>4</td> </tr> <tr> <td>A</td> <td>US 2006/0102331 A1 (CARRIER CORP.) 18 May 2006 (2006-05-18) entire text, all drawings</td> <td>1-9</td> </tr> <tr> <td>A</td> <td>CN 110168303 A (VALEO SYSTEMES THERMIQUES) 23 August 2019 (2019-08-23) entire text, all drawings</td> <td>1-9</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	JP 2012-2475 A (MITSUBISHI ELECTRIC CORP.) 05 January 2012 (2012-01-05) paragraphs [0001], [0012]-[0030], fig. 1-8	1-3, 8-9	Y		2-4	A		5-7	X	JP 2010-139196 A (SHARP CORP.) 24 June 2010 (2010-06-24) paragraphs [0030]-[0049], fig. 1-7	1, 8-9	Y		2-4	A		5-7	Y	JP 2011-17505 A (MITSUBISHI ELECTRIC CORP.) 27 January 2011 (2011-01-27) paragraphs [0014]-[0016], fig. 4	4	A	US 2006/0102331 A1 (CARRIER CORP.) 18 May 2006 (2006-05-18) entire text, all drawings	1-9	A	CN 110168303 A (VALEO SYSTEMES THERMIQUES) 23 August 2019 (2019-08-23) entire text, all drawings	1-9
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Date of the actual completion of the international search 27 October 2021	Date of mailing of the international search report 09 November 2021																													
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.																													

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/037091

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/0290465 A1 (DELPHI TECHNOLOGIES, INC.) 01 December 2011 (2011-12-01) entire text, all drawings	1-9

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/037091

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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JP 2010-139196 A	24 June 2010	(Family: none)	
JP 2011-17505 A	27 January 2011	(Family: none)	
US 2006/0102331 A1	18 May 2006	US 2010/0218924 A1 entire text, all drawings US 2011/0042049 A1 WO 2006/055276 A2	
CN 110168303 A	23 August 2019	WO 2018/100310 A1 entire text, all drawings FR 3059410 A1	
US 2011/0290465 A1	01 December 2011	EP 2392886 A2 entire text, all drawings KR 10-2011-0132273 A CN 202216453 U	

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