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(54) **REFRIGERANT DISTRIBUTOR, HEAT EXCHANGER, AND AIR-CONDITIONING APPARATUS**

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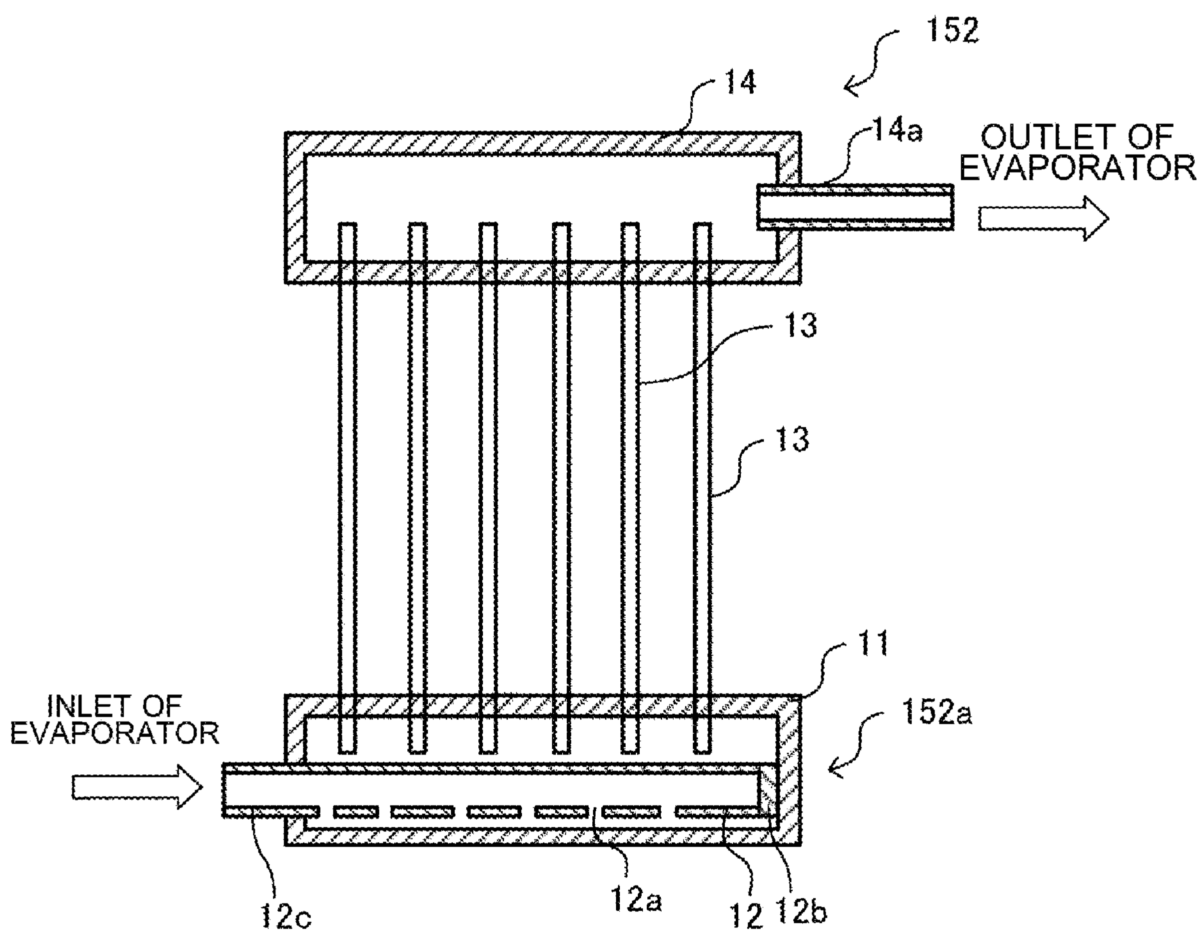
(57) **ABSTRACT**

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.



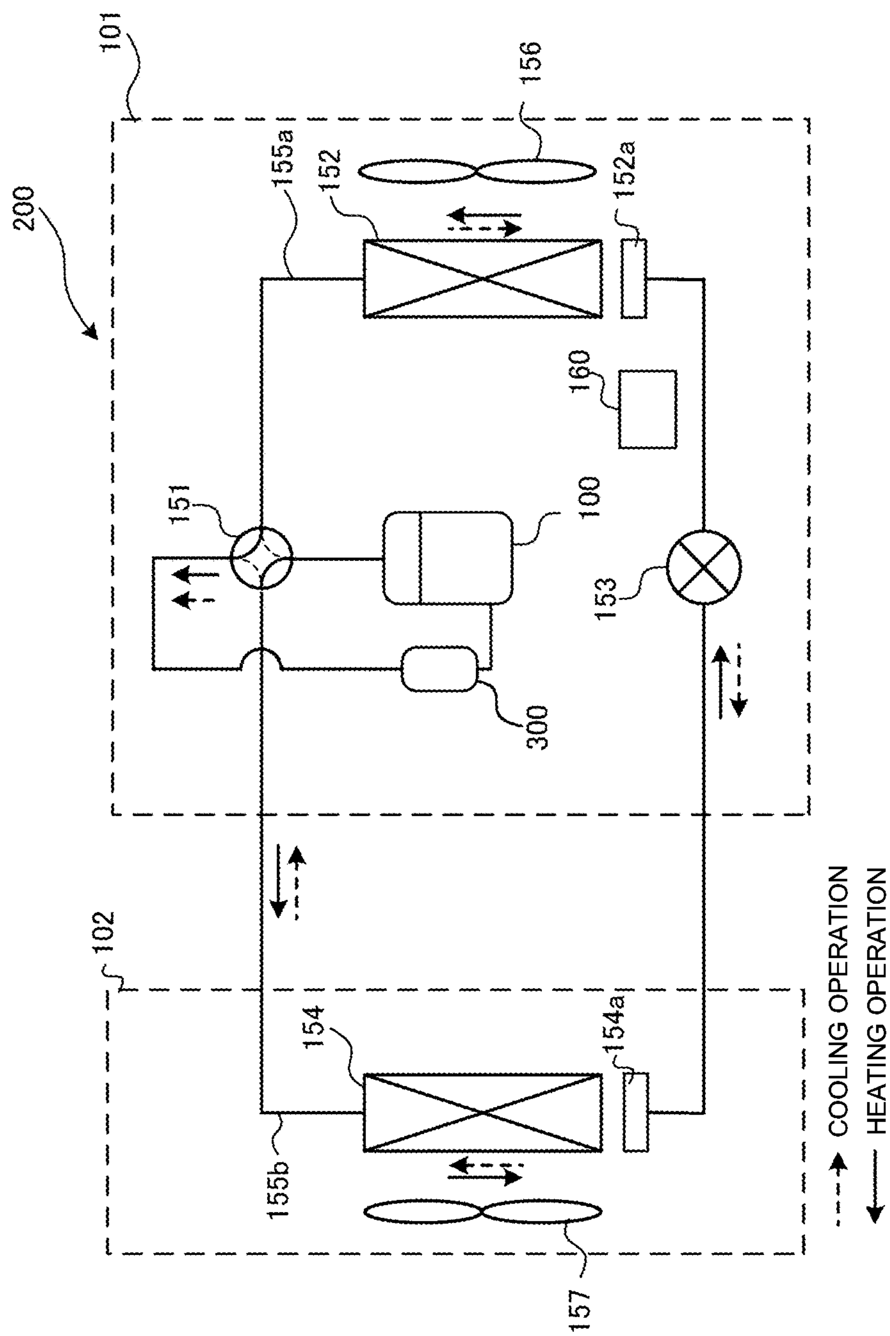

200
101
156
155a
152
152a
160
151
100
153
300
102
154
154a
155b
157
COOLING OPERATION
HEATING OPERATION

FIG. 1

FIG. 2

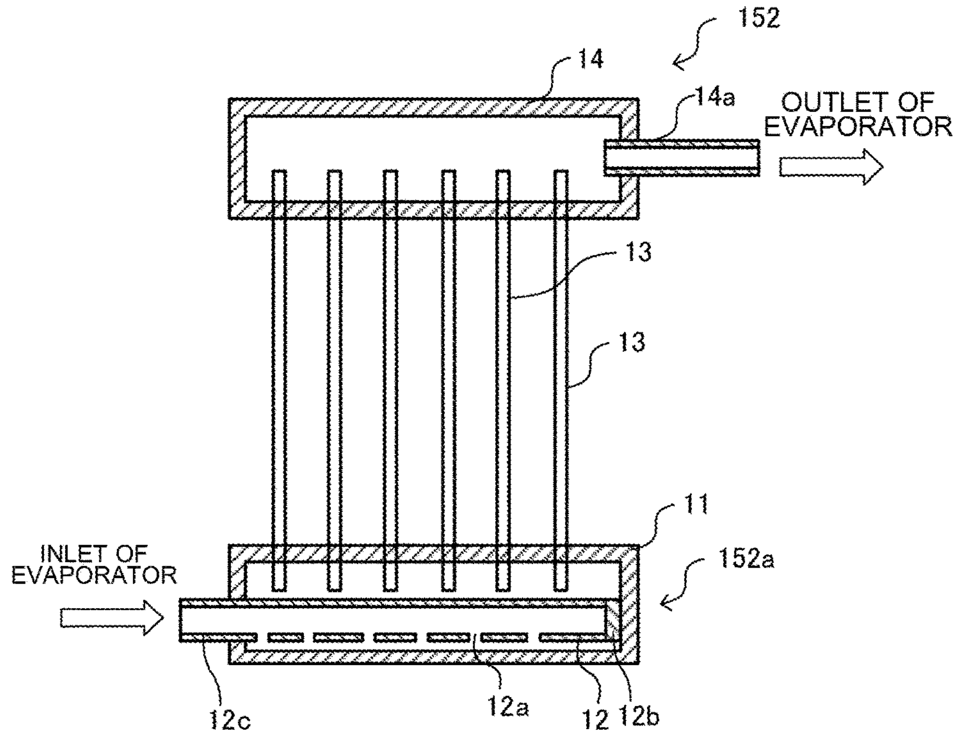

152
14
14a
OUTLET OF EVAPORATOR
13
13
11
INLET OF EVAPORATOR
152a
12c
12a
12
12b

FIG. 3

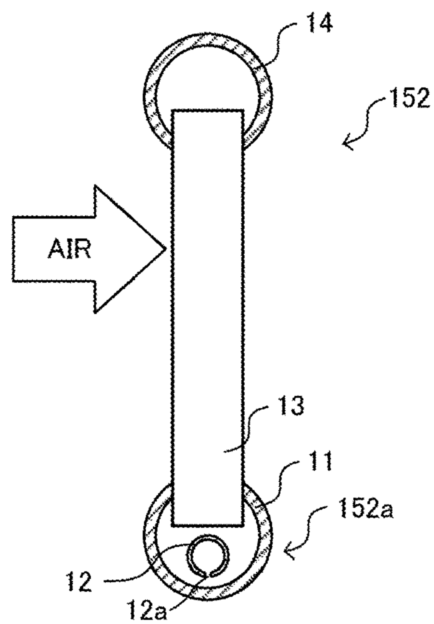

14
152
AIR
13
11
152a
12
12a

FIG. 4

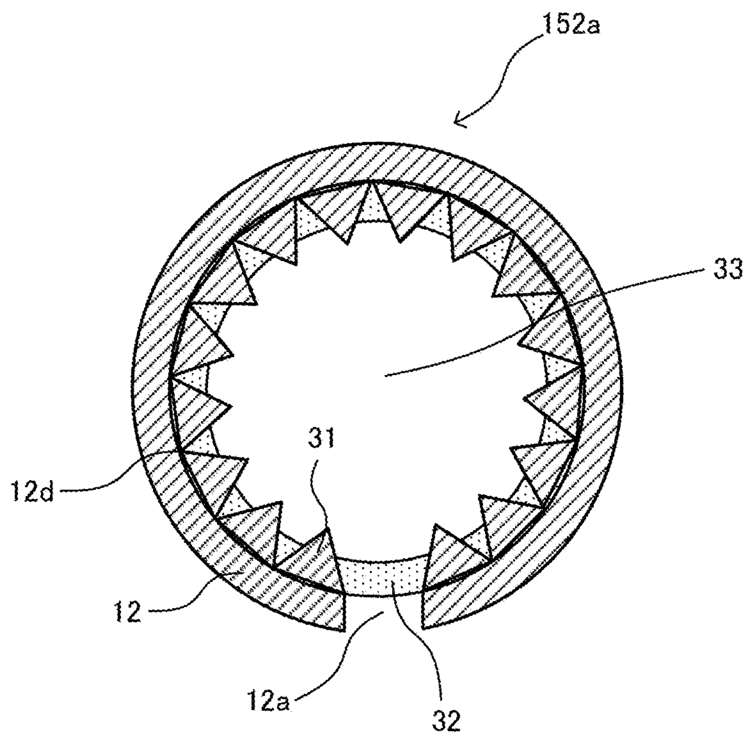


FIG. 5

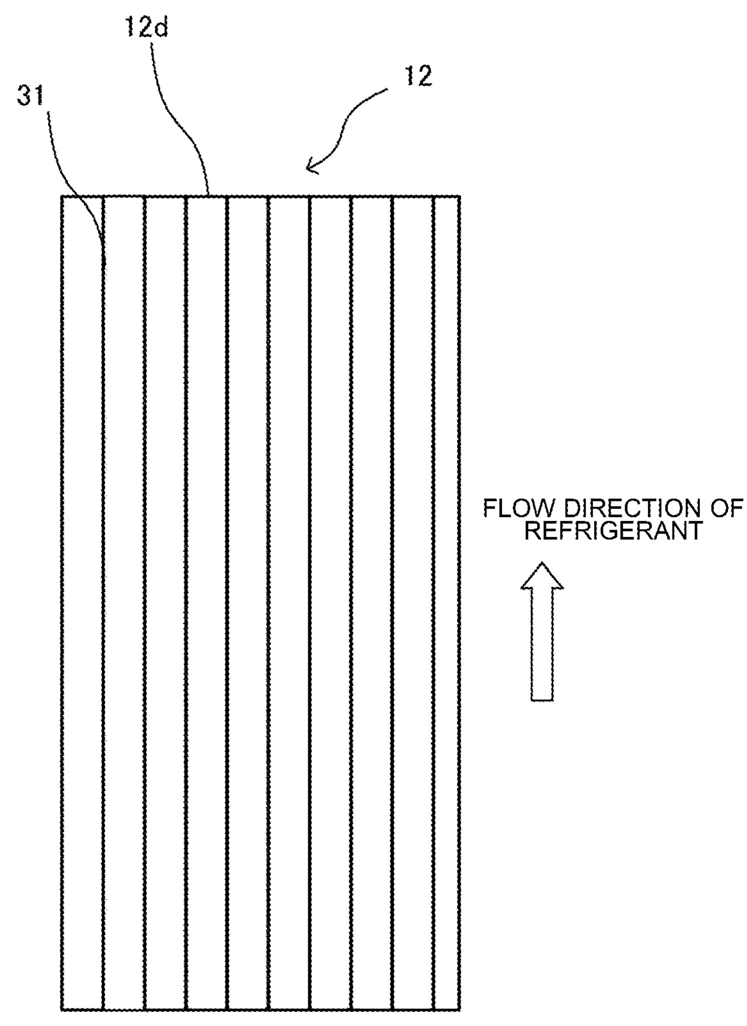


FIG. 6

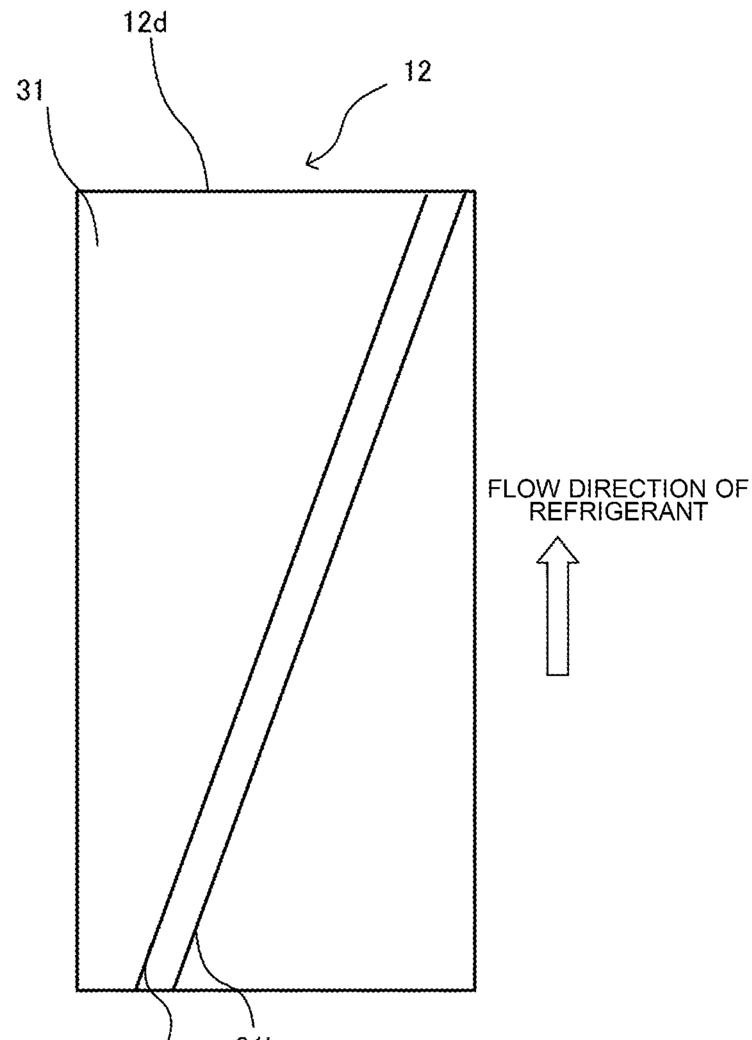


FIG. 7

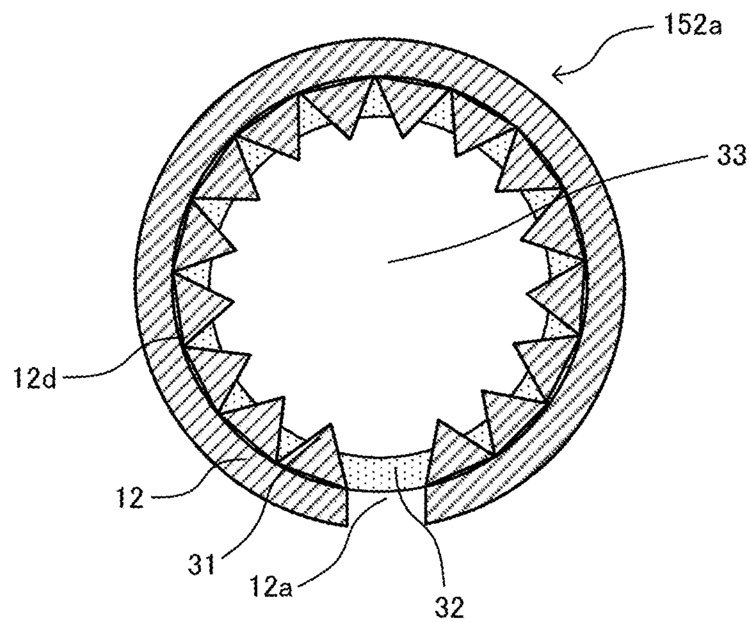


FIG. 8

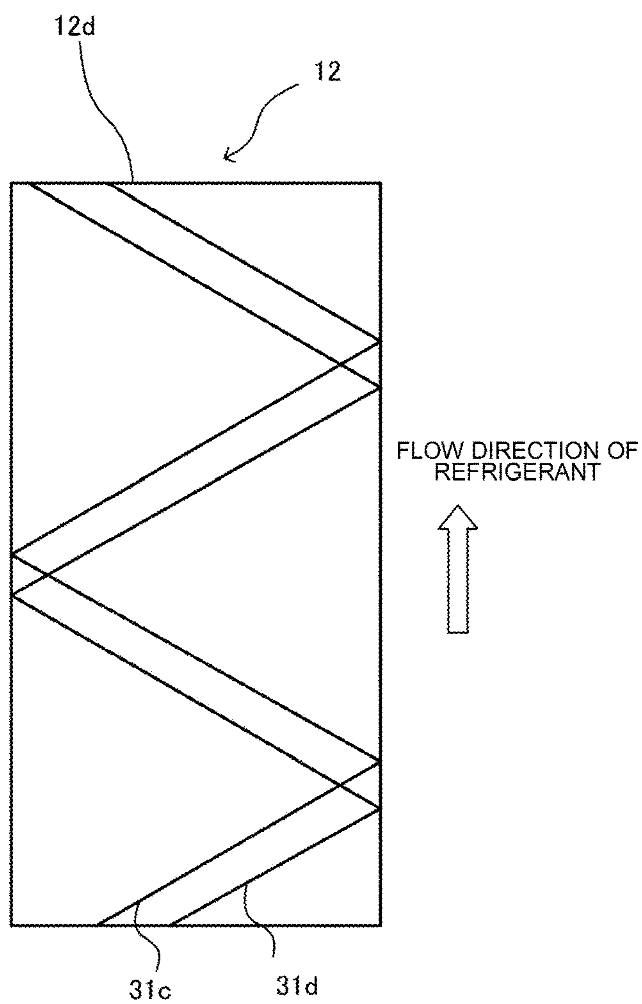

12d
12
FLOW DIRECTION OF
REFRIGERANT
31c
31d

FIG. 9

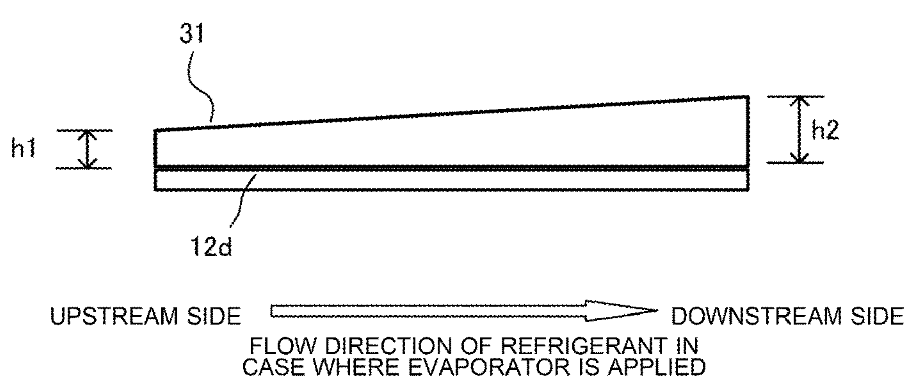

31
h1
h2
12d
UPSTREAM SIDE
DOWNSTREAM SIDE
FLOW DIRECTION OF REFRIGERANT IN
CASE WHERE EVAPORATOR IS APPLIED

FIG. 10

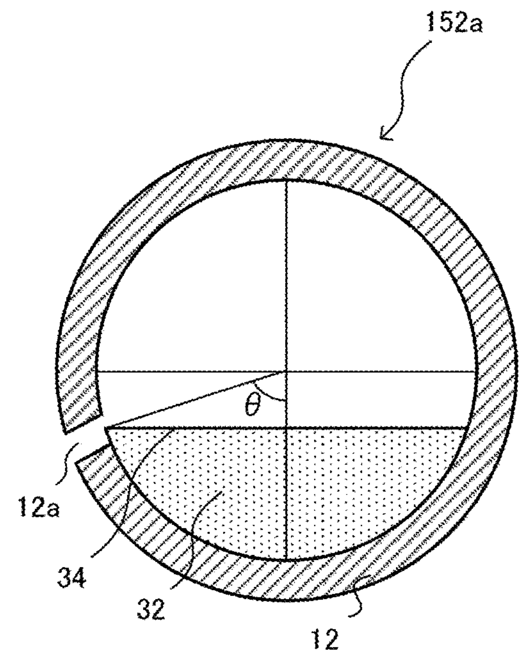

152a
θ
12a
34
32
12

FIG. 11

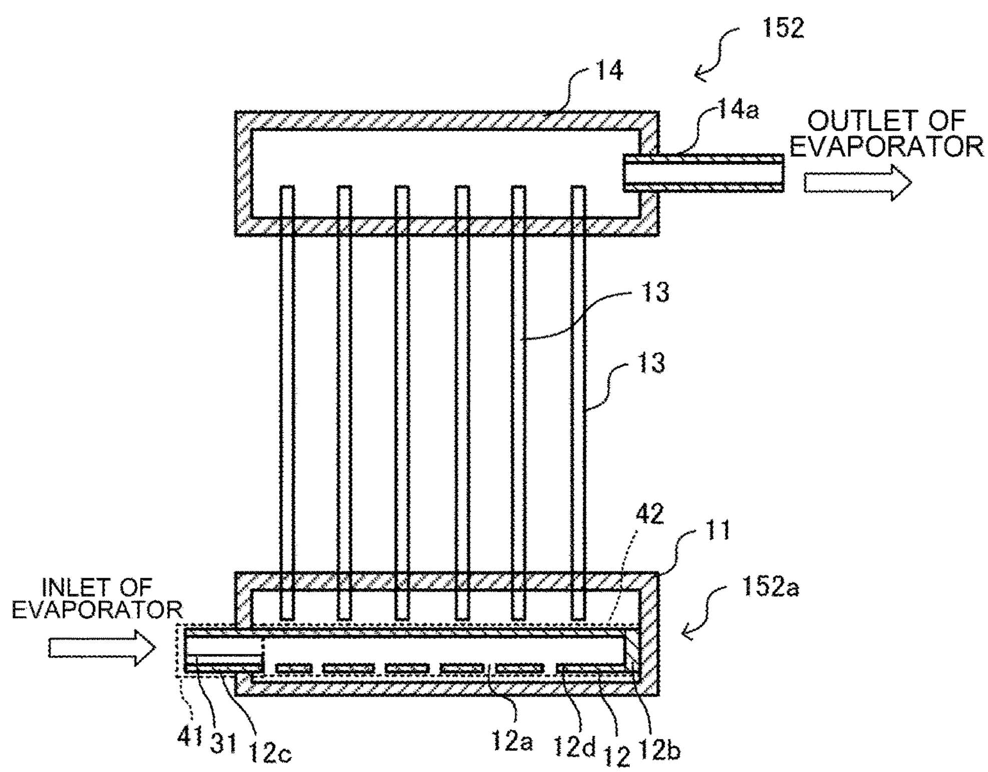
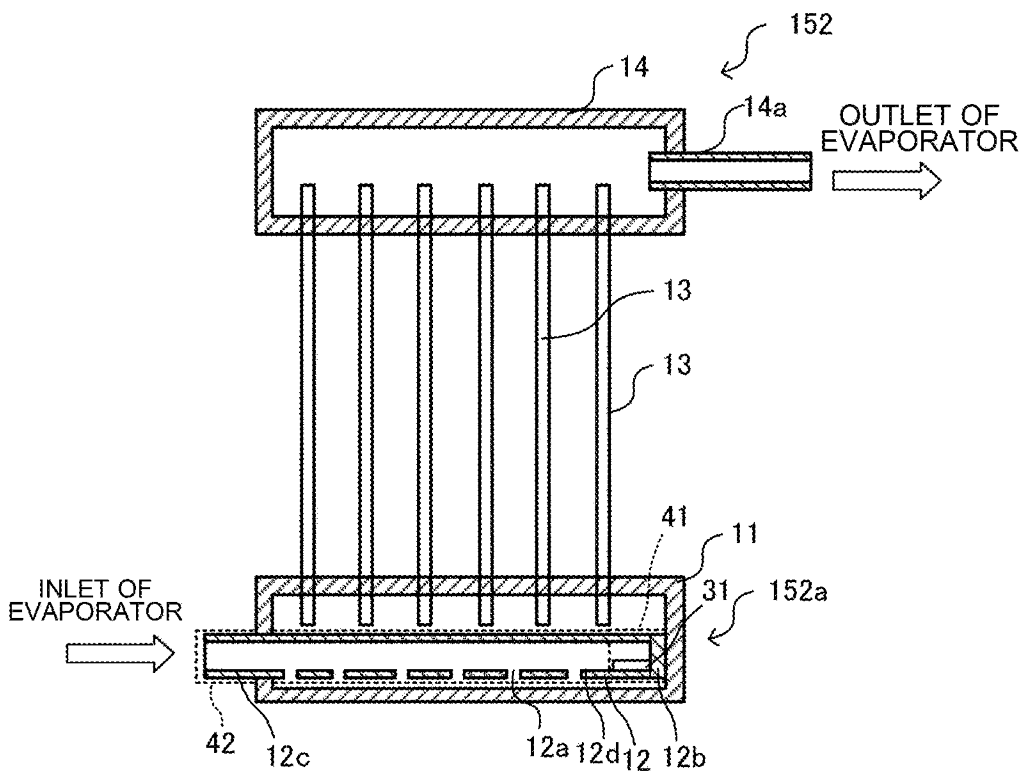

152
14
14a
OUTLET OF
EVAPORATOR
13
13
42
11
152a
INLET OF
EVAPORATOR
41
31
12c
12a
12d
12
12b

FIG. 12


152
14
14a
OUTLET OF
EVAPORATOR
13
13
41
11
31
152a
INLET OF
EVAPORATOR
42
12c
12a
12d
12
12b

REFRIGERANT DISTRIBUTOR, HEAT EXCHANGER, AND AIR-CONDITIONING APPARATUS

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 reduced.

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

[0010] 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.

[0011] 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.

[0012] 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.

[0013] 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.

[0014] 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.

[0015] 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.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] 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.

[0020] 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

[0021] 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

[0022] 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 **152***a,* and a second heat exchanger **154** provided with a second refrigerant distributor **154***a.*

Configuration of Refrigeration Cycle Apparatus 200

[0023] 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 **152***a* is provided. The first refrigerant distributor **152***a* 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**.

[0024] The indoor unit **102** includes the second heat exchanger **154**. At the second heat exchanger **154**, the second refrigerant distributor **154***a* is provided. The second refrigerant distributor **154***a* 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**.

[0025] The compressor **100**, the first heat exchanger **152**, and the expansion device **153** are connected by pipes **155***a,* and the expansion device **153**, the second heat exchanger **154**, and the compressor **100** are connected by pipes **155***b,* whereby a refrigerant circuit is formed.

[0026] 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**.

[0027] 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**.

[0028] 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.

[0029] 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.

[0030] 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.

[0031] The first refrigerant distributor **152***a* 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 **154***a* 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**.

[0032] 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.

[0033] 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**.

[0034] 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.

[0035] 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.

[0036] It should be noted that FIG. **1** illustrates the case where at the first heat exchanger **152**, the first refrigerant distributor **152*a*** is provided, and at the second heat exchanger **154**, the second refrigerant distributor **154*a*** 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.

Operation of Refrigeration Cycle Apparatus **200**

[0037] 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.

[0038] 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).

[0039] 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 **154*a*,** 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 **154*a*** 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.

[0040] 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**.

[0041] 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**.

[0042] 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.

[0043] 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**

[0044] 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.

[0045] 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 **154*a*** of the second heat exchanger **154** has the same configuration as the first refrigerant distributor **152*a*** 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.

[0046] 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 **152***a* 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 **152***a*, 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 **14***a* is provided in such a manner as to communicate with the inside of the gas header **14**. The outflow member **14***a* is connected to the pipe **155***a* connected to the compressor **100**.

First Refrigerant Distributor **152***a*

[0047] As illustrated in FIGS. **2** and **3**, the first refrigerant distributor **152***a* 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**.

[0048] The first refrigerant distributor **152***a* 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.

[0049] 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 **12***b* 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 **155***a* 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.

[0050] As illustrated in FIGS. **2** and **3**, dispersion holes **12***a* 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 **12***a* are arranged apart from each other in the extending direction of the inner tube **12**. The dispersion holes **12***a* each have a diameter of 0.5 mm to 4 mm. The dispersion holes **12***a* 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 **152***a* can be improved, as compared with the case where the dispersion holes **12***a* 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 **12***c* into which the refrigerant flows.

[0051] FIG. **4** illustrates a cross section of the inner tube **12** of the first refrigerant distributor **152***a* 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 **152***a*. FIG. **5** is an explanatory view for the extending direction of projections **31** formed on an inner wall **12***d* of the inner tube **12** in the first refrigerant distributor **152***a* in Embodiment 1.

[0052] As illustrated in FIG. **4**, the projections **31** are arranged on the inner wall **12***d* 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**.

[0053] 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.

[0054] 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 **12***a*, and is uniformly distributed to the heat transfer tubes **13**.

Operation of First Heat Exchanger **152**

[0055] 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.

[0056] Referring to FIG. **2**, the two-phase gas-liquid refrigerant that has flowed into the inflow portion **12***c* of the inner tube **12** flows in the inner tube **12** and are dispersed from the dispersion holes **12***a* 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 **14***a*.

[0057] As illustrated in FIG. **4**, the liquid refrigerant **32** of the two-phase gas-liquid refrigerant that has flowed into the inflow portion **12***c* 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.

[0058] The two-phase gas-liquid refrigerant that flows in the inner tube **12** passes through the dispersion holes **12***a* 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 **12***a,* 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**.

[0059] 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 **14***a* of the gas header **14** through the gas header **14**. The gas refrigerant output from the outflow member **14***a* of the gas header **14** passes through the pipe **155***a,* and returns to the compressor **100** through the flow switching device **151** and the accumulator **300**.

MODIFICATION

[0060] 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 **12***d* of the inner tube **12** in the first refrigerant distributor **152***a* according to Embodiment 1. FIG. **6** illustrates two of the projections **31**, that is, a projection **31***a* and a projection **31***b,* as representatives of the projections **31**. As illustrated in FIG. **6**, the projection **31***a* and the projection **31***b* extend in the direction inclined to the extending direction of the inner tube **12**.

[0061] In the first refrigerant distributor **152***a* and the second refrigerant distributor **154***a* in the refrigeration cycle 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 **31***a* and **31***b* formed on the inner wall **12***d* of the inner tube **12**. Thus, the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes **12***a* 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 **152***a* and the second refrigerant distributor **154***a,* the two-phase gas-liquid refrigerant is uniformly distributed to the heat transfer tubes **13** through the dispersion holes **12***a* regardless which of the heating operation and the cooling operation is performed.

Embodiment 2

[0062] 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 **152***a* and the second refrigerant distributor **154***a* is different from that in Embodiment 1.

[0063] FIG. **7** illustrates a cross section of the inner tube **12** of the first refrigerant distributor **152***a* in the refrigeration cycle apparatus **200** according to Embodiment 2. The cross section of the inner tube **12** in the first refrigerant distributor **152***a* is a cross section perpendicular to the extending direction of the inner tube **12**.

[0064] As illustrated in FIG. **7**, the projections **31** are arranged in the circumferential direction on the inner wall **12***d* 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**.

[0065] FIG. **8** is an explanatory view for the extending direction of the projections **31** formed on the inner wall **12***d* of the inner tube **12** in the first refrigerant distributor **152***a* according to Embodiment 2. FIG. **8** illustrates two of the projections **31**, that is, a projection **31***c* and a projection **31***d,* as representatives of the projections **31**. Referring to FIG. **8**, the projection **31***c* and the projection **31***d* 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 **31***c* and **31***d,* 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 **152***a,* the second refrigerant distributor **154***a* also has the same configuration as the first refrigerant distributor **152***a*.

[0066] 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 **12***d* 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 **12***a* and is uniformly distributed to the heat transfer tubes **13**, regardless of the flow rate of the refrigerant.

[0067] In the first refrigerant distributor **152***a* 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 **12***d* 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 **31***c* and **31***d.* As a result, the two-phase gas-liquid refrigerant is uniformly dispersed from the dispersion holes **12***a* and is uniformly distributed to the heat transfer tubes **13** regardless of the amount of the refrigerant.

Embodiment 3

[0068] 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 **152***a* and the second refrigerant distributor **154***a* is different from that in Embodiment 1.

[0069] FIG. **9** indicates the height of each of the projections **31** formed on the inner wall **12***d* of the inner tube **12** in the first refrigerant distributor **152***a* 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 **152***a* serves as an evaporator. As illustrated in FIG. **9**, the height h**2** of part of the projection **31** from the inner wall **12***d* 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 **12***d* 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 **152***a*, the second refrigerant distributor **154***a* also has the same configuration as the first refrigerant distributor **152***a*.

[0070] 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 **12***a*. 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 **12***d* 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.

[0071] In the first refrigerant distributor **152***a* according to Embodiment 3, the height h**2** of part of the projection **31** from the inner wall **12***d* 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 h**1** of part of the projection **31** from the inner wall **12***d* of the inner tube **12** that is located on the upstream side of the two-phase gas-liquid refrigerant.

[0072] 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 **12***d* is increased.

[0073] 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.

[0074] In the first refrigerant distributor **152***a* of the refrigeration cycle apparatus **200** according to Embodiment 3, the height h**2** of the part of the projection **31** which is located on the downstream side is set greater than the height h**1** 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 **12***d*. Therefore in the first refrigerant distributor **152***a* of the refrigeration cycle apparatus **200** according to Embodiment 3, the two-phase gas-liquid refrigerant uniformly flows out from the dispersion holes **12***a* and is uniformly distributed to the heat transfer tubes **13**.

Embodiment 4

[0075] 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 **12***a* 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 **12***a* of the inner tube **12** in the first refrigerant distributor **152***a* are different from those in Embodiment 1. It should be noted that the positions of the dispersion holes **12***a* of the inner tube **12** in the second refrigerant distributor **154***a* are the same as those in the first refrigerant distributor **152***a*.

[0076] 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 **12***a* of the inner tube **12** in the first refrigerant distributor **152***a* according to Embodiment 4.

[0077] 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 **12***a* satisfies the following formulas (1) and (2):

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

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

[0078] 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 tringle by a trigonometric function from a liquid cross section calculated from the void fraction α.

[0079] In such a manner, the dispersion holes **12***a* 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.

[0080] Therefore, in the first refrigerant distributor **152***a* and the second refrigerant distributor **154***a* 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 **12***a*. Thus, the refrigerant can be uniformly distributed to the heat transfer tubes **13**.

Embodiment 5

[0081] 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 **12***d* of the inner tube **12** in the first refrigerant distributor **152***a*. It should be noted that the positions of the projections **31** in the second refrigerant distributor **154***a* are the same as the positions of the projections **31** in the first refrigerant distributor **152***a*.

[0082] 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 **12***d* 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.

[0083] 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 caser where the first heat exchanger **152** serves as an evaporator.

[0084] 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 **12***a*. The projections **31** are formed on the inner wall **12***d* of the inflow portion **12***c* 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 **12***d* of part of the inner tube **12** that is coated in the smooth portion **42** is smooth.

[0085] 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 **12***d* in the smooth portion **42**.

[0086] Therefore, in the first refrigerant distributor **152***a* according to Embodiment 5, since the projections **31** are formed on the inner wall **12***d* 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 **12***d* 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 **12***a* and is uniformly distributed to the heat transfer tubes **13**.

Embodiment 6

[0087] 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 **12***d* of the inner tube **12** in the first refrigerant distributor **152***a* 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 **154***a* are the same as those of the projections **31** in the first refrigerant distributor **152***a*.

[0088] 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 **12***d* 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.

[0089] 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.

[0090] 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 **12***d* 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 **12***a,* and formed on the inner wall **12***d* of part of the inner tube **12** that is located downstream of the region in which the heat transfer tubes **13** are located.

[0091] 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 **12***d* 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.

[0092] Therefore, in the first refrigerant distributor **152***a* according to Embodiment 6, since the projections **31** are provided on the inner wall **12***d* of part of the inner tube **12** that is located on the downstream side in the flow the two-phase gas-liquid refrigerant, the liquid refrigerant flows along the inner wall **12***d* 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 **12***a* which are located around a downstream end portion where the projections **31** are located, and are uniformly distributed to the heat transfer tubes **13**.

[0093] 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

[0094] **11**: outer tube, **12**: inner tube, **12***a*: dispersion hole, **12***b*: cap, **12***c*: inflow portion, **12***d*: inner wall, **13**: heat transfer tube, **14**: gas header, **14***a*: outflow portion, **31**, **31***a*-**31***d*: 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, **152***a*: first refrigerant distributor, **153**: expansion device, **154**: second heat exchanger, **154***a*: second refrigerant distributor, **155***a*, **155***b*: pipe, **156**: outdoor fan, **157**: indoor fan, **160**: controller, **200**: refrigeration cycle apparatus, **300**: accumulator, h**1**: height of projection on upstream side in flow of two-phase gas-liquid refrigerant, h**2**: 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

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 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):

$$\theta - 20 < \varphi < 180 \tag{1}$$

$$\alpha = 1 - \theta/180 + \sin\theta\cos\theta/\pi \tag{2}$$

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

2. (canceled)

3. (canceled)

4. (canceled)

5. (canceled)

6. 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,
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, and
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. 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,
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, and
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. (canceled)

9. (canceled)

10. The refrigerant distributor of claim **1**, 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.

11. The refrigerant distributor of claim **10**, wherein the projection is formed to helically extend in the extending direction of the inner tube.

12. The refrigerant distributor of claim **10**, wherein the projection is formed to extend in a direction inclined to the extending direction of the inner tube.

13. The refrigerant distributor of claim **10**, 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.

14. A heat exchanger comprising the refrigerant distributor of claim **1**.

15. An air-conditioning apparatus comprising the heat exchanger of claim **14**.

* * * * *