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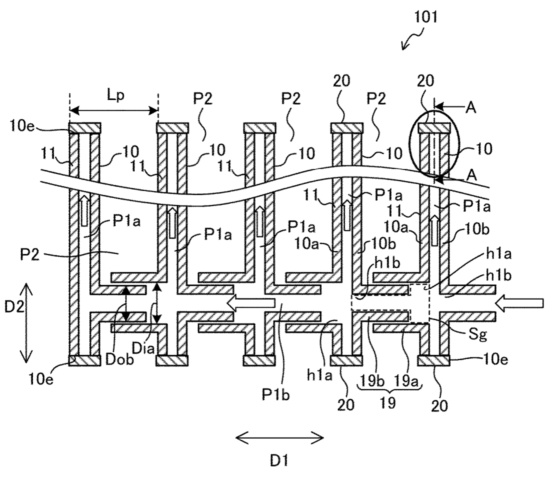
(54) **HEAT EXCHANGER AND AIR CONDITIONER INCLUDING SAME**

(57) A heat exchanger includes flat tubes arranged in a first direction and extending in a second direction crossing the first direction. The flat tubes each include a tube wall having a heat transfer passage in which a fluid flows in an internal space. The tube wall includes tube-side wall portions facing each other in the first direction, formed in the shape of a flat plate, and having through holes. Any adjacent ones of the flat tubes include a connection portion that connects the tube walls of the adjacent flat tubes and causes the heat transfer passages in the tube walls to communicate with each other. The connection portion includes one or more connecting projections formed at an associated one or ones of the tube-side wall portions of the adjacent flat tubes and projecting in the first direction from an associated one or ones of peripheral portions of the through holes.

FIG. 4



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Description

Technical Field

[0001] The present invention relates to a headerless heat exchanger and an air-conditioning apparatus including the heat exchanger.

Background Art

[0002] Among heat exchangers, a heat exchanger is present that includes a plurality a plurality of heat exchange elements stacked together and causes heat exchange to be performed between a first fluid such as refrigerant and a second fluid such as air. A headerless heat exchanger is disclosed as an example of such a heat exchanger as described above (see, for example, Patent Literature 1). The heat exchanger disclosed in Patent Literature 1 includes a plurality of heat transfer passages that are arranged as flow passages for the first fluid in the stacking direction of heat exchange elements having a substantially rectangular shape and that each extend in the longitudinal direction of the heat exchange elements, and header passages that extend in the stacking direction of the heat exchange elements and that cause the plurality of heat transfer passages to communicate with each other.

[0003] In the heat exchanger of Patent Literature 1, each of the heat exchange elements is a plate, and projections and recesses that are formed on and in the plate form the heat transfer passages for the refrigerant between the plate and an adjacent plate on one side of the plate in the stacking direction. Furthermore, air passages are formed between the plate and an adjacent plate on the other side of the plate in the stacking direction. In addition, part where the plate and the adjacent plate on the other side of the plate in the stacking direction are joined to each other has through holes to cause the heat transfer passages for the refrigerant to communicate with each other.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication JP 2020 - 176 791 A

Summary of the Invention

Technical Problem

[0005] However, the heat exchanger in Patent Literature 1 is formed by stacking the plates, the projections and the recesses of the plate form the heat transfer passages for the refrigerant and the air passages, and the through holes of the part where the plates are joined to each other form the header passages for the refrigerant. Thus, the plate pitch and the total width of the heat transfer passages for the refrigerant and the air passages in the stacking direction of the plates are determined by the sizes of the projections and the recesses of the plate (that is, the groove depth or the projection height).

[0006] The width of the air passages in the stacking direction of the plates can be changed based on the sizes of the projections and the recesses. However, the plate is directly processed to have projections and recesses. Thus, there are limitations on a change in the sizes of the projections and the recesses. In addition, when the width of the air passages is increased, the width of the heat transfer passages for the refrigerant is reduced. Accordingly, the heat exchanger of Patent Literature 1 has limited flexibility in design of the air passages.

[0007] The present invention is applied to solve the above problem, and relates to improvement of the flexibility in the design of air passages in a headerless heat exchanger.

Solution to the Problem

[0008] A first heat exchanger according to an embodiment of the present invention is a heat exchanger including a plurality of flat tubes arranged in a first direction and extending in a second direction crossing the first direction. The flat tubes each include a tube wall having a heat transfer passage in which a fluid flows in an internal space of the heat transfer passage. The tube wall includes tube-side wall portions facing each other in the first direction, formed in the shape of a flat plate, and having through holes. Any adjacent ones of the flat tubes include a connection portion that connects the tube walls of the adjacent flat tubes and causes the heat transfer passages in the tube walls to communicate with each other. The connection portion includes one or more connecting projections formed at an associated one or ones of the tube-side wall portions of the adjacent flat tubes and projecting in the first direction from an associated one or ones of peripheral portions of the through holes.

[0009] In addition, an air-conditioning apparatus according to another embodiment of the present invention includes a refrigerant circuit in which a compressor, the above heat exchanger, an expansion valve, and an indoor heat exchanger are connected by refrigerant pipes and the fluid circulates.

Advantageous Effects of Invention

[0010] In the heat exchanger and the air-conditioning apparatus including the heat exchanger according to the embodiments of the present invention, the heat transfer passages for a fluid are provided in the respective tube walls of the flat tubes, any adjacent ones of the flat tubes include the connection portion connecting the tube walls of the adjacent flat tubes and causing the heat transfer passages in the tube walls to communicate with each other, and the connection portion projects in the first direction from the peripheral portion of the through hole of the tube-side wall portion. It is therefore possible to change the width of the air passage located outside the connection portion in the first direction by changing the length of the connection portion. Thus, it is possible to increase the width of the air passage in the first direction without reducing the width of the heat transfer passage for a fluid in the first direction. As a result, it is possible to increase the flexibility in the design of the air passage in a headerless heat exchanger.

Brief Description of Drawings

[0011]

FIG. 1 is a perspective view illustrating a schematic configuration of a heat exchanger according to Embodiment 1.

FIG. 2 is a refrigerant circuit diagram of an air-conditioning apparatus in which the heat exchanger as illustrated in FIG. 1 is mounted.

FIG. 3 is a perspective view illustrating a configuration of a flat tube of the heat exchanger as illustrated in FIG. 1.

FIG. 4 is a vertical sectional view of the heat exchanger in FIG. 1.

FIG. 5 is a partial sectional view that is taken along line A-A of a part surrounded by an ellipse illustrated in FIG. 4.

FIG. 6 is a perspective view illustrating a schematic configuration of a heat exchanger according to Embodiment 2.

FIG. 7 is a vertical sectional view of the heat exchanger as illustrated in FIG. 6.

FIG. 8 illustrates a configuration example of a connection portion surrounded by a quadrilateral in FIG. 7.

FIG. 9 is a perspective view illustrating a configuration of a heat exchanger according to Embodiment 3.

FIG. 10 is a perspective view illustrating a schematic configuration of a heat exchanger according to Embodiment 4.

FIG. 11 is a vertical sectional view of the heat exchanger as illustrated in FIG. 10.

FIG. 12 is a cross-sectional view of a section of plane B of the heat exchanger as illustrated in FIG. 10 as viewed from above.

FIG. 13 is a cross-sectional view of a section of plane C of the heat exchanger in FIG. 10 as viewed from above.

FIG. 14 is a perspective view illustrating a schematic configuration of a heat exchanger according to Embodiment 5.

FIG. 15 is a vertical sectional view illustrating a configuration of a position-regulation portion of a flat tube of a heat exchanger according to Embodiment 6.

Description of Embodiments

[0012] A heat exchanger according to Embodiment 1 will be described with reference to the drawings, for example. For example, in figures in the drawings that include Fig.1 and will be referred to below, relationships in relative size between components and shapes thereof may differ from actual ones. In each of the figures, components that are the same as or equivalent to those in a previous figure or previous figures are denoted by the same reference signs, and this is true of the entire text of the specification. Terms that indicate directions (for example, "up", "down", "right", "left", "forward", and "backward") will be used as appropriate in order that descriptions be easily understood.

[0013] However, these terms are merely used as a matter of convenience and do not limit the locations or the orientations of apparatuses, devices, or components. In the specification, basically, the positional relationships between the components, the directions in which the components extend, and the directions in which the components are arranged are those after a heat exchanger is set in a usable state.

Embodiment 1

[0014] FIG. 1 is a perspective view illustrating a schematic configuration of the heat exchanger according to Embodiment 1. As illustrated in FIG. 1, a heat exchanger 101 includes a plurality of flat tubes 10 that are arranged in a first direction D1 and connected to each other. The flat tubes 10 extend in a direction in which a tube axis Ax extends (which will be hereinafter also referred to as a tube axis direction) and are each elongated and long in one direction in a section perpendicular to the tube axis Ax. Hereinafter, the first direction D1 in which the plurality of flat tubes 10 are arranged may be referred to as a stacking direction, the tube axis direction of the flat tubes 10 may be referred to as a second direction D2 or a longitudinal direction of each of the flat tubes 10, and the longitudinal direction of a section of the flat tube 10 may be referred to as a third direction D3 or a width direction of the flat tube 10. In addition, the following description is made on the assumption that as illustrated in FIG. 1, the heat exchanger 101 is set such that the stacking direction (the first direction D1) of the flat tubes 10 is a lateral direction, the tube axis Ax of the flat tube 10 is an up-down direction orthogonal to the stacking direction (first direction D1), and the width direction (the third direction D3) of the flat tube 10 is a front-back direction orthogonal to the tube axis direction and the stacking direction.

[0015] The location of the heat exchanger 101 or the angle between the staking direction (the first direction D1) and the tube axis direction (the second direction D2) of each of the flat tubes 10 in the heat exchanger 101 is not limited to that in the above case. For example, the heat exchanger 101 may be inclined such that the tube axis direction of each flat tube 10 is inclined relative to the up-down direction. Alternatively, in the case where the heat exchanger 101 is set such that the stacking direction (first direction D1) of the flat tubes 10 is the lateral direction, the heat exchanger 101 may be formed such that the tube axis direction of each of the flat tubes 10 is inclined relative to the up-down direction.

[0016] Spaces that are air passages P2 are provided between tube walls 11 of adjacent ones of the flat tubes 10 in the stacking direction (first direction D1). In each of the spaces in the heat exchanger 101, air flows in the width direction (the third direction D3) of the flat tube 10.

[0017] A first pipe a and a second pipe b that serve as an inlet and an outlet for a fluid (for example, refrigerant), respectively, at the heat exchanger 101 are provided at one of the flat tubes 10 that is provided at one end thereof in the stacking direction. It should be noted that the fluid that flows in the flat tubes 10 may be refrigerant, water or brine, for example. In the heat exchanger 101, flow passages for the fluid are provided between the first pipe a and the second pipe b. The flow passages for the fluid are provided in the plurality of flat tubes 10. The heat exchanger 101 is configured to cause heat exchange to be performed between air and the fluid. In the following description, it is assumed that the fluid that flows in the plurality of flat tubes 10 is the refrigerant.

[0018] Any adjacent two of the flat tubes 10 are provided with a connection portion 19 for connecting the tube walls 11 of the adjacent flat tubes 10. Each flat tube 10 includes the tube wall 11 and a connecting projection 19a or 19b (see FIG. 3 to be described later) included in the connection portion 19 and extending outwardly from the tube wall 11 in the first direction D1. The flat tube 10 has a tube structure having an internal space in which the refrigerant flows and that extends throughout in the longitudinal direction (the second direction D2) of the flat tube 10, that is, from an upper end to a lower end of the tube wall 11. The structure of the flat tube 10 will be described in detail later.

[0019] End portions of the flat tube 10 on both sides in the longitudinal direction (second direction D2) of the flat tube 10 are sealed. Specifically, the heat exchanger 101 includes tube sealing portions 20 that seal respective open ends 10e on the both sides of the flat tube 10 in the longitudinal direction (the second direction D2) of the flat tube 10. In an example illustrated in FIG. 1, the tube sealing portions 20 are provided at respective two positions on the upper side and the lower side of each flat tube 10. The tube sealing portions 20 are joined to respective open ends 10e of the flat tube 10 by joining means such as soldering or an adhesive.

[0020] FIG. 2 is a refrigerant circuit diagram of an air-conditioning apparatus 100 in which the heat exchanger 101 as illustrated in FIG. 1 is mounted. As illustrated in FIG. 2, in the air-conditioning apparatus 100, the heat exchanger 101 forms part of a refrigerant circuit 100c in which refrigerant circulates.

[0021] The air-conditioning apparatus 100 includes a compressor 102, the heat exchanger 101, an expansion valve 105, an indoor heat exchanger 104, and a four-way valve 103. Referring to FIG. 2, the compressor 102, the heat exchanger 101, the expansion valve 105, and the four-way valve 103 are provided in an outdoor unit 100A, and the indoor heat exchanger 104 is provided in an indoor unit 100B. The first pipe a and the second pipe b (see FIG. 1), which serve as the inlet and the outlet for refrigerant at the heat exchanger 101, are connected to the four-way valve 103 and the expansion valve 105 of the refrigerant circuit 100c.

[0022] The compressor 102, the heat exchanger 101, the expansion valve 105, the indoor heat exchanger 104, and the four-way valve 103 are connected by refrigerant pipes, whereby the refrigerant circuit 100c is formed in which the refrigerant can circulate. The air-conditioning apparatus 100 carries out a refrigeration cycle in which the refrigerant circulates in the compressor 102, the heat exchanger 101, the expansion valve 105, and the indoor heat exchanger 104 while changing its phase, when the compressor 102 operates.

[0023] An outdoor fan 107 is provided in the outdoor unit 100A, and forcibly causes outdoor air to pass through the heat exchanger 101. The heat exchanger 101 causes heat exchange to be performed between the refrigerant and a flow of outdoor air generated by operation of the outdoor fan 107. An indoor fan 106 is provided in the indoor unit 100B, and forcibly causes indoor air to pass through the indoor heat exchanger 104. The indoor heat exchanger 104 causes heat exchange to be performed between the refrigerant and a flow of indoor air generated by operation of the indoor fan 106.

[0024] The operation of the air-conditioning apparatus 100 can be switched between a cooling operation and a heating operation. In FIG. 2, dashed arrows indicate the flow direction of the refrigerant in the cooling operation, and solid arrows indicate the flow direction of the refrigerant in the heating operation. The four-way valve 103 is a solenoid valve configured to switch the refrigerant passage according to the switching between the cooling operation and the heating operation of the air-conditioning apparatus 100. In the cooling operation, the four-way valve 103 guides refrigerant flowing from the compressor 102 to the heat exchanger 101 and guides refrigerant flowing from the indoor heat exchanger 104 to the compressor 102. In the heating operation, the four-way valve 103 guides refrigerant flowing from the compressor 102 to the indoor heat exchanger 104 and guides refrigerant flowing from the heat exchanger 101 to the compressor 102.

[0025] In the cooling operation of the air-conditioning apparatus 100, refrigerant compressed in the compressor 102 is sent to the heat exchanger 101. In the heat exchanger 101, the refrigerant is condensed by transferring heat to outdoor air. Then, the refrigerant is sent to the expansion valve 105, is decompressed by the expansion valve 105, and is then sent to the indoor heat exchanger 104. Thereafter, the refrigerant is evaporated in the indoor heat exchanger 104 by receiving heat from indoor air and then returns to the compressor 102. Thus, in the cooling operation of the air-conditioning apparatus 100, the heat exchanger 101 serves as a condenser, and the indoor heat exchanger 104 serves as an evaporator.

[0026] In the heating operation of the air-conditioning apparatus 100, refrigerant compressed in the compressor 102 is sent to the indoor heat exchanger 104. In the indoor heat exchanger 104, the refrigerant is condensed by transferring heat to indoor air. Then, the refrigerant is sent to the expansion valve 105, is decompressed by the expansion valve 105, and is then sent to the heat exchanger 101. Thereafter, the refrigerant is evaporated in the heat exchanger 101 by receiving heat from outdoor air and then returns to the compressor 102. Thus, in the heating operation of the air-conditioning apparatus 100, the heat exchanger 101 serves as an evaporator, and the indoor heat exchanger 104 serves as a condenser.

[0027] FIG. 3 is a perspective view illustrating a configuration of the flat tube 10 of the heat exchanger 101 as illustrated in FIG. 1. FIG. 4 is a vertical sectional view of the heat exchanger 101 as illustrated in FIG. 1. FIG. 5 is a partial sectional view that is taken along line A-A of a part surrounded by an ellipse illustrated in FIG. 4. A configuration of the refrigerant passages and the flat tubes 10 of the heat exchanger 101 will be described in detail below with reference to FIGS. 1 to 5. In FIGS. 1, 4, and 5, solid outline arrows indicate the flow direction of the refrigerant in the case where the heat exchanger 101 is used as a condenser. In addition, in FIG. 5, dashed outline arrows indicate the flow direction of air.

[0028] As illustrated in FIGS. 3 to 5, the tube wall 11 includes tube-side wall portions 10a and 10b that are located to face each other in the first direction D1 and formed in the shape of a flat plate, and connecting wall portions 10c and 10d that connect the tube-side wall portions 10a and 10b at respective end portions of the tube-side wall portions 10a and 10b on the respective sides in the third direction D3 and have a curved shape. The tube-side wall portions 10a and 10b each have a rectangular shape whose long sides extend in the longitudinal direction (the second direction D2) of the flat tube 10 and whose short sides extend in the width direction (third direction D3) of the flat tube 10. The tube-side wall portions 10a and 10b are formed in the shape of a flat plate, but it is not indispensable that the "shape of the flat plate" in the present application is the shape of a plate that is completely flat.

[0029] It suffices that it appears to be formed in the shape of a flat plate as a whole. For example, part of a flatly spreading region may have recesses, projections, or a corrugated portion. Referring to FIG. 4, a left wall portion of the tube wall 11 is the tube-side wall portion 10a, and a right wall portion of the tube wall 11 is the tube-side wall portion 10b. As illustrated in FIG. 4, the tube-side wall portion 10a on the left side has a through hole h1a passing through the tube-side wall portion 10a in the first direction D1, and the tube-side wall portion 10b on the right side has a through hole h1b passing through the tube-side wall portion 10b in the first direction D1.

[0030] The connection portion 19 of any adjacent ones of the flat tubes 10 is formed in the shape of a cylinder having a hollow portion Sg passing through the connection portion 19 in the first direction D1. The connection portion 19 includes at least one of the connecting projection 19a that extends from a peripheral portion of the through hole h1a of the tube-side wall portions 10a of one of the adjacent flat tubes 10 toward the opposite tube-side wall portion 10b and the connecting projection 19b that extends from a peripheral portion of the through hole h1b of the tube-side wall portion 10b of the other of the adjacent flat tube 10 toward the opposite tube-side wall portion 10a.

[0031] In an example illustrated in FIG. 4, the connection portion 19 includes the connecting projections 19a and 19b, which are respectively formed at the opposite tube-side wall portions 10a and 10b of the adjacent flat tubes 10 and are formed in the shape of a cylinder. The through holes h1a and h1b and the connecting projections 19a and 19b of each flat tube 10 can be formed by, for example, burring processing in which holes are formed in flat-plate part of the flat tubes 10 and flat-plate parts of peripheries of the holes are deformed to be raised and formed in the shape of a cylinder.

[0032] As illustrated in FIG. 4, the connection portion 19 causes the internal spaces of the adjacent tube walls 11 to communicate with each other via the hollow portion Sg connecting the through holes h1a and h1b provided in the tube-side wall portions 10a and 10b. In addition, the connection portion 19 has a function of partitioning off the hollow portion Sg located inward of the connection portion 19 and the air passage P2, which is a space located outside the connection portion 19.

[0033] As illustrated in FIG. 4, the through holes h1a and h1b and the connection portion 19 are formed inward of the open ends 10e on the both sides in the longitudinal direction (the second direction D2) of the flat tube 10. Specifically, in the heat exchanger 101 provided as illustrated in FIG. 1, the through holes h1a and h1b and the connecting projections 19a and 19b of each flat tube 10 are formed below the open end 10e on the upper side of the flat tube 10 and above the open end 1e on the lower side of the flat tube 10.

[0034] For example, the flat tube 10 can be produced in the following manner: the through holes h1a and h1b and the connecting projections 19a and 19b are formed in advance in a material that will form the flat tube 10, and the material is molded into the flat tube 10 by roll-forming. In addition, the connecting projections 19a and 19b may be formed by raising the hole peripheral portions when the through holes h1a and h1b are formed in the material that will form the flat tube 10. For example, the flat tube 10 is made of a metal material having a high thermal conductivity, such as aluminum, copper, or brass.

[0035] The refrigerant passages of the heat exchanger 101 include heat transfer passages P1a that are provided in the respective tube walls 11 of the flat tubes 10 and extend in the longitudinal direction (the second direction D2) of the flat tube 10, and a header passage P1b that extends in the stacking direction (the first direction D1) of the flat tubes 10 (first direction D1) and causes the respective heat transfer passages P1a of the flat tubes 10 to communicate with each other. One end of the header passage P1b extending in the first direction D1 is connected to the first pipe a (see FIG. 1).

[0036] For example, the through holes h1a and h1b and the hollow portions Sg of the connection portions 19 described above form the header passage P1b, and in the hollow portions Sg, the refrigerant flows. In the heat exchanger 101, the connection portions 19 are formed by parts of the flat tubes 10, and parts of the header passage P1b that are provided between the tube walls 11 of the flat tubes 10 are the hollow portions Sg located inward of the connection portions 19. Accordingly, in the heat exchanger 101, the header passage P1b is formed in the flat tubes 10, which are heat exchange elements. Therefore, the heat exchanger 101 does not need to include a header tube in addition to the flat tubes 10. Thus, the structure of the heat exchanger 101 is a headerless structure.

[0037] In an example illustrated in FIG. 5, in each of the flat tubes 10, a first partition 30 is provided to extend in the longitudinal direction (the second direction D2) of the flat tube 10, that is, the up-down direction), and partitions the internal space of the tube wall 11 of the flat tube 10 in the width direction (third direction D3) of the flat tube 10, that is, the front-back direction). Furthermore, an upper end 30e of the first partition 30 is provided below an open end 10e on the upper side of the flat tube 10. Thus, a turning passage P1at in which the refrigerant can flow in the front-back direction (third direction D3) is provided in an upper region of the internal space of the tube wall 11. That is, in the example of FIG. 5, the heat transfer passage P1a for the refrigerant is formed in an inverted U-shape in such a manner as to include the turning passage P1at.

[0038] In the example illustrated in FIGS. 1, 3 to 5, as illustrated in FIG. 4, the refrigerant passages of the heat exchanger 101 include the heat transfer passages P1a, the header passage P1b and a header passage P1c (see FIG. 3). The header passage P1b and the header passage P1c are arranged in parallel in the front-back direction in a lower region of the heat exchanger 101. The header passage P1b is defined, for example, by the hollow portions Sg of the connection portions 19 provided on the front side in the lower region of the heat exchanger 101. In addition, as illustrated in FIG. 3, the header passage P1c is defined, for example, by hollow portions (not illustrated) of a plurality of connection portions 18 provided on the rear side in the lower region of the heat exchanger 101. As illustrated in FIGS. 1 and 4, a right end of the header passage P1b on the front side is connected to the first pipe a, and a right end of the header passage P1c on the rear side is connected to the second pipe b.

[0039] The heat exchanger 101 as illustrated in FIGS. 1, 3 to 5 is an example of the heat exchanger 101 according to the present embodiment of the present invention. It is possible to appropriately change, for example, the shape of the heat transfer passage P1a, the presence or absence of the first partition 30 of the flat tube 10, the location of the first partition 30, and the number of first partitions 30, and the locations of the first pipe a and the second pipe b of the heat exchanger 101.

[0040] Next, an example of the operation of the heat exchanger 101 in the case where the heat exchanger 101 is used as a condenser will be described with reference to FIGS. 1, 2, 4, and 5. As indicated by outlined arrows in FIG. 1, high-temperature and high-pressure gas refrigerant flows from the first pipe a into the heat exchanger 101. As illustrated in FIG. 4, in the heat exchanger 101, the high-temperature and high-pressure gas refrigerant first flows into the header passage P1b extending through the front side of a lower part of each of the plurality of flat tubes 10 in the lateral direction, and flows in the header passage P1b from the right to the left. In this process, the high-temperature and high-pressure gas refrigerant is distributed to and flows into the heat transfer passages P1a provided in the respective tube walls 11 of the flat tubes 10.

[0041] The high-temperature and high-pressure gas refrigerant that has flowed into each heat transfer passage P1a flows upward on the front side of the internal space of the tube wall 11, flows rearward in the turning passage P1at (see FIG. 5) in the upper region of the internal space of the tube wall 11, and then flows downward on the rear side of the internal space of the tube wall 11. In this case, the high-temperature and high-pressure gas refrigerant transfers heat to air flowing in the space between the tube walls 11 of the flat tubes 10 (that is, the air passage P2) and is condensed to change into high-pressure two-phase gas-liquid refrigerant, by exchanging heat with the air via the tube wall 11.

[0042] The high-pressure two-phase gas-liquid refrigerant that has flowed from the heat transfer passages P1a flows into the header passage P1c (see FIG. 3) extending through the rear side of the lower part of each of the plurality of flat tubes 10 and join together in the header passage P1c. As illustrated in FIGS. 1 and 3, the high-pressure two-phase gas-liquid refrigerant that has joined together in the header passage P1c flows out to the outside of the heat exchanger 101 (for example, the expansion valve 105 of the refrigerant circuit 100c as illustrated in FIG. 2) from the second pipe b connected to the header passage P1c.

[0043] As illustrated in FIG. 4, the connection portion 19 connecting the tube walls 11 of the adjacent flat tubes 10 causes the heat transfer passages P1a to communicate with each other and partitions off the refrigerant passage (in particular, the header passage P1b) in the space between the tube walls 11 and the air passage P2 located outward of the connection portion 19. Furthermore, the connection portion 19 includes the connecting projections 19a and 19b each of which is part of the flat tube 10.

[0044] Therefore, in the heat exchanger 101 according to the present embodiment of the present invention, it suffices that the length of the connection portion 19 is set according to a desired tube pitch Lp. Thus, it is possible to change the tube pitch Lp and the width of the air passage P2 in the first direction D1 without reducing the width of the heat transfer passage P1a for the refrigerant in the first direction D1. As a result, it is possible to provide the heat exchanger 101 having high flexibility in the design of the air passages, as compared with an existing heat exchanger in which plates are stacked together.

[0045] As compared with the structure according to the present embodiment of the present invention, in the existing structure in which the heat transfer passages for the refrigerant and the air passages are provided between the stacked plates, the area of the part where the heat exchange elements (in the existing structure, the plates) are joined to each other is increased, thus increasing airflow resistance, deteriorating the capability of draining dew condensation water, or closing the air passages P2 due to frost. In addition, the heat exchange performance is deteriorated by the above problem of increasing the airflow resistance, deteriorating the capability of draining dew condensation water, or closing the air passages P2 due to frost.

[0046] On the other hand, in the heat exchanger 101 according to the present embodiment, it is possible to minimize the area of the part where the heat exchange elements (that is, the flat tubes 10) are joined to each other. In addition, it is sufficient to change the length of the connection portions 19 even in the case of increasing the width of the air passages P2 in the first direction D1. Thus, a change or changes in components can be reduced.

[0047] For example, the connecting projections 19a and 19b included in the connection portion 19 are configured to be fitted to each other. A specific example of this configuration will be described. The connecting projection 19b projecting rightward and having a cylindrical shape is formed at the right tube-side wall portion 10b of the left one of the adjacent flat tubes 10 in the first direction D1. The connecting projection 19a projecting leftward and having a cylindrical shape is formed at the left tube-side wall portion 10a of the right one of the adjacent flat tubes 10 in the first direction D1. An inner diameter Dia of the connecting projection 19a is substantially equal to an outer diameter Dob of the connecting projection 19b. When the flat tubes 10 are stacked, a right distal end portion of the connecting projection 19b is fitted into the connecting projection 19a, whereby the flat tubes 10 are connected. In this case, it is advisable to appropriately determine the length of part of the connecting projection 19b that is fitted into the connecting projection 19a and the lengths of the connecting projections 19a and 19b in the first direction D1 such that each of distal ends of the connecting projections 19a and 19b does not project into the heat transfer passage P1a of the associated opposite flat tube 10 in the case where a tube pitch Lp is set to a desired length.

[0048] It is not indispensable that the connecting projections 19a and 19b are configured to be fitted to each other. For example, the connecting projections 19a and 19b may be configured as follows: the outer diameter Dob of the connecting projection 19b is slightly smaller than the inner diameter Dia of the connecting projection 19a, the right distal end portion of the connecting projection 19b is inserted into the connecting projection 19a such that the tube pitch Lp is a desired length, and the connecting projections 19a and 19b are then joined to each other by a joining means such as soldering or an adhesive.

[0049] The shapes of the connecting projections 19a and 19b forming the connection portion 19 are not limited to the above shapes, and it is sufficient that the connecting projections 19a and 19b are shaped to be capable of partitioning off the header passage P1b for the refrigerant and the air passage P2. In addition, the connecting projections 19a and 19b may be formed to overlap each other in the first direction D1 (see FIG. 4). Alternatively, the connecting projections 19a and 19b may be joined to each other at their distal ends without overlapping each other in the first direction D1. In the configuration in which the connecting projections 19a and 19b overlap each other in the first direction D1, part of the connection portion 19 in the first direction D1 has a double-wall structure. Thus, the strength of the connection portion 19 can be increased, as compared with the configuration in which the distal ends of the connecting projections 19a and 19b are joined to each other.

[0050] As described above, the heat exchanger 101 according to Embodiment 1 of the present invention is the heat exchanger 101 including the plurality of flat tubes 10 arranged in the first direction D1 and each extending in the second direction D2 crossing the first direction D1. The flat tube 10 includes the tube wall 11 having the heat transfer passage P1a in which a fluid flows in the internal space. The tube wall 11 includes the tube-side wall portions 10a and 10b that face each other in the first direction D1 and are formed in the shape of a flat plate. The tube-side wall portions 10a and 10b have the through holes h1a and h1b, respectively. In addition, the adjacent flat tubes 10 include the connection portion 19 connecting the tube walls 11 and causing the heat transfer passages P1a in the tube walls 11 to communicate with each other.

[0051] Furthermore, the connection portion 19 includes one or more connecting projections formed at an associated one or ones of the opposite tube-side wall portions 10a and 10b of the adjacent flat tubes 10 and projecting in the first direction D1 from an associated one or ones of the peripheral portions of the through holes h1a and h1b, that is, the connecting portion 19 includes at least one of the connecting projection 19a that is formed at the tube-side wall portion 10a of one of the adjacent flat tubes 10 and that projects in the first direction D1 from the peripheral portion of the through hole h1a and the connecting projection 19b that is formed at the tube-side wall portion 10b of the other of the adjacent flat tubes 10 and that projects in the first direction D1 from the peripheral portion of the through hole hlb.

[0052] In the heat exchanger 101, the heat transfer passages P1a are provided in the respective tube walls 11 of the flat tubes 10, the adjacent flat tubes 10 include the connection portion 19 connecting the tube walls 11 and causing the heat transfer passages P1a to communicate with each other, and the connection portion 19 includes the connecting projection 19a projecting in the first direction D1 from the peripheral portion of the through hole h1a in the tube-side wall portion 10a and/or the connecting projection 19b projecting in the first direction D1 from the peripheral portion of the through hole h1b in the tube-side wall portion 10b. In the existing heat exchanger, the heat transfer passages for the refrigerant and the air passages are formed by formation of the projections and the recesses directly at the plate, and the through holes of the part where the plates are joined to each other cause the heat transfer passages to communicate with each other.

[0053] Thus, when the width of the air passages is increased, the width of the heat transfer passages for the refrigerant is decreased. By contrast, the heat exchanger 101 according to the present embodiment is configured such that the heat transfer passages P1a for a fluid are provided in the flat tubes 10, and the connection portion 19 causing the heat transfer passages P1a to communicate with each other projects in the first direction D1 from the tube-side wall portion 10a or 10b. Therefore, the width of the air passages P2 (that is, the spaces between the tube walls 11) in the first direction D1 can be changed by changing of the length of the connection portions 19. Thus, it is possible to increase the width of the air passages P2 in the first direction D1 without decreasing the width of the heat transfer passages P1a for a fluid in the first direction D1. As a result, it is possible to increase the flexibility in the design of the air passages in the headerless heat exchanger 101.

[0054] In addition, the connection portion 19 includes the connecting projections 19a and 19b formed at the opposite tube-side wall portions 10a and 10b of the adjacent flat tubes 10. Thus, the connecting projection 19a or 19b does not easily enter the tube wall 11, as compared with the case in which the connection portion 19 includes one of the connecting projections 19a and 19b.

[0055] In addition, the connecting projections 19a and 19b formed at the opposite tube-side wall portions 10a and 10b of the adjacent flat tubes 10 at least overlap each other in the first direction D1. Thus, part of the connection portion 19 can be made to have a double-wall structure. Accordingly, it is possible to increase the strength of the connection portion 19.

[0056] In addition, the flat tube 10 includes the first partition 30 provided in the internal space of the tube wall 11, extending in the second direction D2, and partitioning the internal space in the third direction D3 orthogonal to the first direction D1 and the second direction D2. Then, at least one end (for example, the upper end 30e) of the first partition 30 in the second direction D2 is located inward of the ends on the both sides (open ends 10e on the both sides) of the flat tube 10 in the second direction D2.

[0057] Therefore, it is possible to freely modify the fluid passages. Thus, it is not necessary to provide a bridging header that bridges the flat tubes 10 provided in two rows, for example, in the case where the heat transfer passage P1a is shaped to turn in the up-down direction according to the positions of an inlet and an outlet for a fluid.

Embodiment 2

[0058] FIG. 6 is a perspective view illustrating a schematic configuration of a heat exchanger 101b according to Embodiment 2. FIG. 7 is a vertical sectional view of the heat exchanger 101b as illustrated in FIG. 6. FIG. 8 illustrates a configuration example of a connection portion 19 surrounded by a quadrilateral in FIG. 7. In FIGS. 6 and 8, solid outline arrows indicate the flow direction of the refrigerant in the case where the heat exchanger 101b is used as a condenser. The heat exchanger 101b according to Embodiment 2 will be described with reference to FIGS. 6 to 8. The heat exchanger 101b according to Embodiment 2 differs from the heat exchanger 101 according to Embodiment 1 in the configuration of the tube sealing portions 20. It should be noted that components having the same functions and operations as those in Embodiment 1 will be denoted by the same reference signs, and their descriptions will be omitted.

[0059] In the heat exchanger 101 according to Embodiment 1, the tube sealing portions 20 are provided at the respective positions of the upper side and the lower side of each flat tube 10. However, in the heat exchanger 101b according to Embodiment 2, two tube sealing portions 120 common to the plurality of flat tubes 10 are provided at respective positions of the upper side and the lower side of the plurality of flat tubes 10.

[0060] As illustrated in FIG. 6, the tube sealing portions 120 are formed of substantially rectangular plate elements covering the open ends 10e of the plurality of flat tubes 10. The open ends 10e of the plurality of flat tubes

10 are fixed to the tube sealing portions 120 at a constant pitch. Specifically, as illustrated in FIG. 7, each of the tube sealing portions 120 has groove portions 120r and flat portions 120p between the groove portions 120r. In the tube sealing portion 120, the groove portions 120r are formed at a constant pitch Lr in the stacking direction (the first direction D1) of the flat tubes 10 and extend in the width direction (third direction D3) of the flat tubes 10 along the open ends 10e of the flat tubes 10. The pitch Lr of the groove portions 120r of the tube sealing portion 120 is equal to the tube pitch Lp of the flat tubes 10. The end portions including the open ends 10e of the flat tubes 10 are provided in the respective groove portions 120r of the tube sealing portions 120. The width of the groove portion 120r in the first direction D1 is substantially equal to or slightly greater than the thickness of the flat tube 10 in the first direction D1.

[0061] In the tube sealing portion 120 located on the lower side, the flat portions 120p other than the parts (that is, the groove portions 120r) closing the open ends 10e on the lower side of the flat tubes 10 each have a drain hole 120h through which water such as dew condensation water or defrosted water generated on the flat tubes 10 is let out.

[0062] When the flat tubes 10 are stacked during production of the heat exchanger 101b, the end portions of the flat tubes 10 in the longitudinal direction are inserted into the groove portions 120r of the tube sealing portions 120, with the opposite connecting projections 19a and 19b of the adjacent flat tubes 10 engaged with each other. Thus, the plurality of flat tubes 10 are arranged at the constant tube pitch Lp in the first direction D1. Thereafter, the groove portions 120r of the tube sealing portions 120 and the end portions of the flat tubes 10 in the longitudinal direction are joined to each other, and the connecting projections 19a and 19b of the adjacent flat tubes 10 are joined to each other by a joining means such as soldering or an adhesive. Then, the open ends 10e of the flat tubes 10 are fixed to the tube sealing portions 120 by the joining means. Thus, it is possible to increase the strength of closure of the open ends 10e, which are the ends of the flat tubes 10 in the longitudinal direction.

[0063] As illustrated in FIG. 7, in a configuration in which the positions of the flat tubes 10 in the stacking direction (first direction D1) are determined by the tube sealing portions 120, it is preferable that the connecting projections 19a and 19b be slightly engaged with each other so that the distance between the tube walls 11 of the adjacent flat tubes 10 can be easily adjusted, when the flat tubes 10 are stacked, as compared with the case in which the connecting projection 19b is fitted into the connecting projection 19a.

[0064] An example of the above configuration will be described with reference to FIG. 8. Referring to FIG. 8, the connecting projections 19a and 19b included in the connection portion 19 of the adjacent flat tubes 10 are formed in the shape of a cylinder that is coved such that the opening sizes of the distal ends are larger than those of the proximal ends. The connecting projection 19b is formed at the peripheral portion of the through hole h1b of the tube-side wall portion 10b, and the connecting projection 19a is formed at the peripheral portion of the through hole h1a of the tube-side wall portion 10a. The through hole h1b is smaller than the through hole h1a. When the flat tubes 10 are stacked and the connecting projection 19b is inserted into the connecting projection 19a, the distal end of the connecting projection 19b is caught by an inner surface of the connecting projection 19a.

[0065] Thus, as compared with a configuration in which the connecting projections 19a and 19b included in the connection portion 19 are fitted to each other, in the configuration in which the connecting projections 19a and 19b are slightly engaged with each other, it is possible to reduce the contact area between the connecting projections 19b and 19b and thus reduce the frictional force therebetween. Thus, when the plurality of flat tubes 10 are set at the tube sealing portions 120, it is easy to adjust the distance between the tube walls 11 of the adjacent flat tubes 10.

[0066] It is possible to form the connecting projections 19a and 19b as illustrated in FIG. 8 by raising the hole peripheral portions when the through holes h1a and h1b are formed in a material that will form the flat tube 10, for example, as well as the connecting projections 19a and 19b as illustrated in FIG. 4.

[0067] As described above, in addition to the configuration of the heat exchanger 101 according to Embodiment 1, the heat exchanger 101b according to Embodiment 2 has the tube sealing portion 120 formed in the shape of a plate, provided at at least one end (open end 10e) of each of the flat tubes 10 in the second direction D2, and covering one end of the heat transfer passage P1a of each flat tube 10. Furthermore, the one end (open end 10e) of each flat tube 10 is fixed to an associated one of the groove portions 120r that are formed in the tube sealing portion 120 at the constant pitch Lr. Since the end portions of the flat tubes 10 are inserted into the groove portions 120r, the above configuration is superior in strength. Instead of the groove portions 120r, projecting portions (not illustrated) may be formed as uneven structures of the tube sealing portions 120 to be coupled to the end portions of the flat tubes 10. The projecting portions may be inserted into the respective end portions of the flat tubes 10 by using the tube sealing portions 120 in which the projecting portions are formed at the constant pitch Lr.

[0068] Thus, it is possible to arrange the flat tubes 10 at the constant tube pitch Lp by using the tube sealing portions 120 while maintaining a sufficient heat exchange area.

Embodiment 3

[0069] FIG. 9 is a perspective view illustrating a configuration of a heat exchanger 101c according to Embodiment 3. In FIG. 9, solid outline arrows or dashed outline arrows indicate the flow direction of the refrigerant in the case where the heat exchanger 101c is used as a condenser. The heat exchanger 101c according to Embodiment 3 will be described with reference to FIG. 9. In the heat exchanger 101c according to Embodiment 3, heat transfer fins 50 are provided. In this regard, the heat exchanger 101c according to Embodiment 3 differs from the heat exchanger 101b according to Embodiment 2. Components having the same functions and operations as those in Embodiment 2 will be denoted by the same reference signs, and their descriptions will thus be omitted.

[0070] The heat exchanger 101c according to Embodiment 3 includes, for example, corrugated fins, as the heat transfer fins 50, provided in the respective spaces, that is, the air passages P2, between the plurality of flat tubes 10, and connecting the opposite tube-side wall portions 10a and 10b of the adjacent flat tubes 10. In this case, the heat transfer fins 50 and each of the opposite tube-side wall portions 10a and 10b of the adjacent flat tubes 10 are joined to each other by soldering. With this configuration, heat exchange between the refrigerant and air is promoted and the heat exchange performance of the heat exchanger 101c is improved.

[0071] In addition, the heat exchanger 101c according to Embodiment 3, as well as the heat exchanger 101 according to Embodiment 1 has high flexibility in the design of the air passages P2. Thus, addition of the heat transfer fins 50 is easy. It should be noted that it suffices that the pitch Lr of the groove portions 120r of the tube sealing portion 120 is set based on a desired tube pitch Lp.

[0072] As described above, in the heat exchanger 101c according to Embodiment 3, the heat transfer area is increased because of addition of the heat transfer fins 50 and the heat exchange performance can be improved.

Embodiment 4

[0073] FIG. 10 is a perspective view illustrating a schematic configuration of a heat exchanger 101d according to Embodiment 4. FIG. 11 is a vertical sectional view of the heat exchanger 101d as illustrated in FIG. 10. FIG. 12 is a cross-sectional view of a section of a plane B of the heat exchanger 101d as illustrated in FIG. 10 as viewed from above. FIG. 13 is a cross-sectional view of a section of a plane C of the heat exchanger 101d as illustrated in FIG. 10 as viewed from above. In FIGS. 10 to 12, solid outline arrows indicate the flow direction of the refrigerant in the case where the heat exchanger 101d is used as a condenser.

[0074] In addition, in FIGS. 12 and 13, a dashed outline arrow indicates the flow direction of air. The heat exchanger 101d according to Embodiment 4 will be described with reference to FIGS. 10 to 13. In the heat exchanger 101d according to Embodiment 4, the positions of the first pipe a and the second pipe b are changed. In this regard, the heat exchanger 101d according to Embodiment 4 differs from the heat exchanger 101b according to Embodiment 2. In addition, as the result of the change in positions of the first and second pipes, the refrigerant passages are also changed. Components having the same functions and operations as those in Embodiment 1 will be denoted by the same reference signs, and their descriptions will be omitted.

[0075] As illustrated in FIG. 10, in the heat exchanger 101d according to Embodiment 4, the second pipe b is provided at a flat tube 110 located at one end of a plurality of flat tubes 110 in the stacking direction, and the first pipe a is provided at a flat tube 110 provided at the other end of the plurality of flat tubes 110 in the stacking direction. Specifically, the first pipe a is provided at the center, in the front-back direction, of lower part of the leftmost one of the flat tubes 110, and the second pipe b is provided at the center, in the front-back direction, of lower part of the rightmost one of the flat tubes 110.

[0076] In the heat exchanger 101d, the first partition 30 (see FIG. 6 relating to Embodiment 2) is not provided in a tube wall 111 of each flat tube 110. As illustrated in FIG. 11, the heat exchanger 101d includes a second partition 40 that partitions the header passage P1b in the stacking direction (the first direction D1) of the flat tubes 110. The second partition 40 blocks the flow of the refrigerant in the first direction D1 between the heat transfer passages P1a adjacent to each other. Specifically, the second partition 40 is provided at, for example, a connection portion 119, the through hole h1a of a tube-side wall portion 110a, or the through hole h1b of a tube-side wall portion 110b.

[0077] In an example illustrated in FIG. 11, one second partition 40 is provided in the header passage P1b connected to the first pipe a, and partitions the header passage P1b into a header passage region P1b1 located on the left side and a header passage region P1b2 located on the right side. The second partition 40 is provided so as to be visible from the outside and between a connecting projection 119b of the flat tube 110 on the left side and a connecting projection 119a of the flat tube 110 on the right side. That is, at the position where the second partition 40 is provided, the distal ends of the connecting projection 119a and the connecting projection 119b are joined to the second partition 40.

[0078] As illustrated in FIGS. 10 and 11, the refrigerant passages of the heat exchanger 101d are the plurality of heat transfer passages P1a, and the header passage P1b and a header passage P1d, which are respectively provided in parallel in a lower part and an upper part of the heat exchanger 101d at the center of the heat exchanger 101d in the front-back direction. The header passage P1b is defined by, for example, the hollow portions Sg of a plurality of the connection portions 119 provided in the lower part of the heat exchanger 101d. The header passage P1d is defined by, for example, hollow portions (not illustrated) of a plurality of connection portions 117 provided in the upper part of the heat exchanger 101d. The left end of the header passage P1b on the lower side is connected to the first pipe a, and the right end of the header passage P1b on the lower side is connected to the second pipe b.

[0079] Each of the connection portions 117 on the upper side, as well as each of the connection portions 119 on the lower side, each includes at least one of a connecting projection 117a that extends from a peripheral portion of a through hole h2a of the tube-side wall portion 110a of one of the adjacent flat tubes 110 toward the opposite tube-side wall portion 110b and a connecting projection 117b that extends from a peripheral portion of a through hole h2b of the tube-side wall portion 110b of the other of the adjacent flat tubes 110 toward the opposite tube-side wall portion 110a.

[0080] In the heat exchanger 101d, the first partition 30 (see FIG. 6 relating to Embodiment 2) is not provided in the tube wall 111 of each flat tube 110. Thus, the internal space of the tube wall 111 serves as the one heat transfer passage P1a that is I-shaped.

[0081] The second partition 40 is provided in the header passage P1b on the lower side and between the tube walls 111 of at least one pair of adjacent ones of the plurality of flat tubes 110. That is, a plurality of second partitions 40 may be provided in the header passage P1b on the lower side. In this case, one or more second partitions 40 are also provided in the header passage P1d on the upper side, thereby forming a meandering refrigerant passage.

[0082] Next, an example of the operation of the heat exchanger 101d in the case where the heat exchanger 101d is used as a condenser will be described with reference to FIGS. 2 and 10 to 13. As illustrated in FIG. 10, high-temperature and high-pressure gas refrigerant flows from the first pipe a into the heat exchanger 101d. As illustrated in FIG. 11, in the heat exchanger 101d, the high-temperature and high-pressure gas refrigerant first flows into the header passage region P1b1 located on the left side of the header passage P1b passing through the lower part of each of the plurality of flat tubes 110 and flows in the header passage region P1b1 from the left to the right. In this process, the high-temperature and high-pressure gas refrigerant is distributed to and flows into the heat transfer passages P1a provided in the respective tube walls 111 of some flat tubes 110 on the left side of the flat tubes 110.

[0083] The high-temperature and high-pressure gas refrigerant that has flowed into the heat transfer passages P1a of some flat tubes 110 on the left side flow upward in the internal spaces of the tube walls 111 and then join together in the header passage P1d (see FIG. 12) extending through an upper part of each of the flat tubes 110. Thereafter, in a process in which the refrigerant that has joined together flows rightward in the header passage P1d, the refrigerant is distributed to and flows into the heat transfer passages P1a of some flat tubes 110 on the right side of the flat tubes 110 and then flows downward. As illustrated in FIG. 13, when flowing upward in the heat transfer passages P1a of some flat tubes 110 on the left side and when flowing downward in the heat transfer passages P1a of some flat tubes 110 on the right side, the high-temperature and high-pressure gas refrigerant transfers heat to air flowing in the space (that is, the air passage P2) between the tube walls 111 of the flat tubes 110 and is condensed to change into high-pressure two-phase gas-liquid refrigerant by exchanging heat with the air via the tube wall 111.

[0084] As illustrated in FIG. 11, the high-pressure two-phase gas-liquid refrigerant that has flowed from the heat transfer passages P1a of the flat tubes 110 on the right side then flows into the header passage region P1b2 on the right side of the header passage P1b and joins together in the header passage region P1b2. The refrigerant that has joined together flows out to the outside of the heat exchanger 101d (for example, the expansion valve 105 of the refrigerant circuit 100c as illustrated in FIG. 2) from the second pipe b.

[0085] As described above, the heat exchanger 101d according to Embodiment 4 includes the second partition 40 that is provided between the tube walls 111 of at least one pair of adjacent ones of the of flat tubes 110 and that blocks the flow of the fluid between the heat transfer passages via the connection portion 119.

[0086] Thus, the header passage P1b can be partitioned by the simple method. In addition, because of the provision of the second partition 40 in the connection portion 119, the resultant structure enables, for example, the hermeticity of the second partition 40 to be checked from the outside.

Embodiment 5

[0087] FIG. 14 is a perspective view illustrating a schematic configuration of a heat exchanger 101e according to Embodiment 5. In FIG. 14, solid outline arrows or dashed outline arrows indicate the flow directions of the refrigerant in the case where the heat exchanger 101e is used as a condenser. The heat exchanger 101e according to Embodiment 5 will be described with reference to FIG. 14. In Embodiment 5, the heat exchanger 101d according to Embodiment 4 including the second partition 40 is configured to additionally include the first partition 30 according to Embodiment 1, and components having the same functions and operations as those in Embodiment 4 will be denoted by the same reference signs and their descriptions will thus be omitted.

[0088] As illustrated in FIG. 14, in the heat exchanger 101e according to Embodiment 5, the second pipe b is provided at a flat tube 210 provided at one end of a plurality of flat tubes 210 in the stacking direction thereof, and the first pipe a is provided at a flat tube 210 provided at the other end of the plurality of flat tubes 210 in the staking direction. Specifically, the first pipe a is provided on the front side of a lower part of the leftmost flat tube 210, and the second pipe b is provided on the front side of a lower part of the rightmost flat tube 210.

[0089] In an example illustrated in FIG. 14, the refrigerant passages of the heat exchanger 101e are the plurality of heat transfer passages P1a, the header passage P1b, and the header passage P1c. The header passage P1b and the header passage P1c are arranged in parallel in the front-back direction in a lower part of the heat exchanger 101e. The header passages P1b is defined by, for example, the respective hollow portions Sg (see FIG. 4) of a plurality of connection portions 219 provided on the front side in the lower part of the heat exchanger 101e. In addition, the header passage P1c are defined by, for example, respective hollow portions (not illustrated) of the plurality of connection portions 18 (see FIG. 3) provided on the rear side in the lower part of the heat exchanger 101e. The left end of the header passage P1b on the front side is connected to the first pipe a, and the right end of the header passage P1b on the front side is connected to the second pipe b.

[0090] In the heat exchanger 101e, as in Embodiment 1, the first partition 30 is provided in a tube wall 211 of each flat tube 210, and the turning passage P1at, in which the refrigerant flows in the front-back direction, is provided in an upper region of the internal space of the tube wall 211. That is, the heat transfer passage P1a for the refrigerant is formed in an inverted U-shape in such a manner as to include the turning passage P1at.

[0091] In addition, the header passage P1b on the front side is partitioned by the second partition 40 into the header passage region P1b1, which is located on the left side and is connected to the first pipe a, and the header passage region P1b2, which is located on the right side and is connected to the second pipe b.

[0092] Next, an example of the operation of the heat exchanger 101e in the case where the heat exchanger 101e is used as a condenser will be described with reference to FIG. 14. High-temperature and high-pressure gas refrigerant flows from the first pipe a into the heat exchanger 101e. In the heat exchanger 101e, the high-temperature and high-pressure gas refrigerant first flows into the header passage region P1b1 on the left side in the header passage P1b on the front side. In a process in which the high-temperature and high-pressure gas refrigerant flows in the header passage region P1b1 from the left to the right, the high-temperature and high-pressure gas refrigerant is distributed to and flows into the heat transfer passages P1a of some ones of the flat tubes 210 that are located on the left side.

[0093] The high-temperature and high-pressure gas refrigerant that has flowed into the heat transfer passages P1a of the above flat tubes 210 on the left side flows upward, rearward, and downward in this order in the internal spaces of the tube walls 211 and then joins together in the header passage P1c on the rear side. Thereafter, in a process in which the refrigerant that has joined together flows rightward in the header passage P1c, the refrigerant is distributed to and flows into the heat transfer passages P1a of some ones of the plurality of flat tubes 210 that are located on the right side, and then flows upward, forward, and downward in this order. When flowing in the heat transfer passages P1a of the flat tubes 210 located on the left side and when flowing in the respective heat transfer passages P1a of the flat tubes 210 located on the right side, the high-temperature and high-pressure gas refrigerant transfers heat to air flowing in the space (that is, the air passage P2) between the tube walls 211 of the flat tubes 210 and is condensed to change into high-pressure two-phase gas-liquid refrigerant by exchanging heat with the air via the tube wall 211.

[0094] The high-pressure two-phase gas-liquid refrigerant that has flowed from the heat transfer passages P1a of the flat tubes 210 located on the right side then flows into the header passage region P1b2 on the right side in the header passage P1b on the front side and joins together in the header passage region P1b2. The refrigerant that has joined together flows from the second pipe b to the outside of the heat exchanger 101e (for example, the expansion valve 105 of the refrigerant circuit 100c as illustrated in FIG. 2).

Embodiment 6

[0095] FIG. 15 is a vertical sectional view illustrating the configuration of a position-regulation portion 315 of a flat tube 310 of a heat exchanger 101f according to Embodiment 6. The heat exchanger 101f according to Embodiment 6 will be described with reference to FIG. 15. The heat exchanger 101f differs from the heat exchanger 101 according to Embodiment 1 in the shape of the flat tube 10. That is, the heat exchanger 101f according to Embodiment 6 includes the position-regulation portion 315 that regulates the distance between tube walls 311 of the adjacent flat tubes 310. In this regard, the heat exchanger 101f according to Embodiment 6 differs from that in Embodiment 1. Components having the same functions and operations as those in Embodiment 1 will be denoted by the same reference signs, and their descriptions will thus be omitted.

[0096] The adjacent flat tubes 310 include the position-regulation portion 315 to maintain a constant distance between the respective tube walls 311. As in Embodiment 1, each flat tube 310 includes the tube wall 311 and connecting projections 319a and 319b that extend outward in the first direction D1 from the tube wall 311 and form a connection portion 319. In addition, in Embodiment 6, each flat tube 310 includes position-regulation projections 315a and 315b that extend outward in the first direction D1 from the tube wall 311 and form the position-regulation portion 315.

[0097] Specifically, in the tube wall 311, a tube-side wall portion 310a and a tube-side wall portion 310b are located to face each other in the first direction D1 and have a substantially flat shape; the tube-side wall portion 310a is a tube-side wall portion at which the position-regulation projection 315a is provided, and the tube-side wall portion 310b is a tube-side wall portion at which the position-regulation projection 315b is provided. Then, the position-regulation projections 315a and 315b provided at the adjacent flat tubes 310 are in contact with each other, thus regulating the distance between the tube walls 311. That is, the position-regulation portion 315 is a spacer provided on the tube walls 311 of the flat tubes 310.

[0098] The position-regulation projections 315a and 315b are each formed in the shape of, for example, a quadrilateral frame as viewed in front view of the heat exchanger 101f. The shape of each of the position-regulation projections 315a and 315b is not limited to the above shape and may be formed in the shape of, for example, a trapezoid or triangular frame. Because of the provision of the position-regulation projections 315a and 315b, the heat transfer area of the heat exchanger 101f is increased and the heat exchange performance of the heat exchanger 101f is improved. It should be noted that the position-regulation projections 315a and 315b are each formed in the shape of a frame shape in order to reduce airflow resistance.

[0099] In an example illustrated in FIG. 15, the position-regulation portion 315 are formed to include both the position-regulation projections 315a and 315b that are provided on the respective adjacent flat tubes 310 but its configuration is not particularly limited to such a configuration. The position-regulation portion 315 may be configured to include only one position-regulation projection provided on one (the tube-side wall portion 310a or 310b) of the tube-side wall portions 310a and 310b of the adjacent flat tubes 310, which are provided to face each other. In this case, the position-regulation projection provided at one of the adjacent flat tubes 310 is in contact with the tube wall 311 of the other flat tube 310.

[0100] As illustrated in FIG. 15, the position-regulation projections 315a and 315b can be formed integrally with the respective flat tubes 310. Specifically, the position-regulation projections 315a and 315b are each formed of part of a material that will form the flat tube 310. For example, in the case where the flat tube 310 is made of a material formed in the shape of a plate, it is sufficient to form the position-regulation projection 315a or 315b at the same time as the through hole h1a and other parts are formed, by forming the flat tube 310 using material including a margin portion in addition to a portion that will become the tube wall 311, and making a cut in part of the margin portion and bending the part thereof.

[0101] The position-regulation projections 315a and 315b may be made of a material different from that for the flat tube 310.

[0102] As described above, in the heat exchanger 101f according to Embodiment 6, at at least one of the tube-side wall portions 310a and 310b of the adjacent flat tubes 310, which face each other, an associated one or ones of the position-regulation projections 315a and 315b that regulate the distance between the tube walls 311 are provided. It is therefore possible to increase the heat transfer area and to regulate the distance between the tube walls 311 of the adjacent flat tubes 310.

[0103] The embodiments are described above, but the present invention is not limited only to the embodiments described above. For example, configurations of the embodiments may be combined. Although the above description concerning Embodiment 3 is made with respect to the case in which the heat transfer fins 50 are applied to the heat exchanger 101b according to Embodiment 2, the heat transfer fins 50 according to Embodiment 3 may be applied to the heat exchanger 101 according to Embodiment 1, 4, 5, or 6. It should be noted that in the case where the heat transfer fins 50 are provided in the heat exchanger 101f according to Embodiment 6, the heat transfer fins 50 are provided in a region of the air passage P2 that is other than regions thereof where the connection portion 319 and the position-regulation portion 315 are provided.

List of Reference Signs

[0104]

10: flat tube,
10a: tube-side wall portion,
10b: tube-side wall portion,
10c: connecting wall portion,
10d: connecting wall portion,
10e: open end,
11: tube wall,
18: connection portion,
19: connection portion,
19a: connecting projection,
19b: connecting projection,
20: tube sealing portion,
30: first partition,
30e: upper end,
40: second partition,
50: heat transfer fin,
100: air-conditioning apparatus,
100A: outdoor unit,
100B: indoor unit,
100c: refrigerant circuit,
101: heat exchanger,
101b: heat exchanger,
101c: heat exchanger,
101d: heat exchanger,
101e: heat exchanger,
101f: heat exchanger,
102: compressor,
103: four-way valve,
104: indoor heat exchanger,
105: expansion valve,
106: indoor fan,
107: outdoor fan,
110: flat tube,
110a: tube-side wall portion,
110b: tube-side wall portion,
111: tube wall,
117: connection portion,
117a: connecting projection,

117b: connecting projection,
119: connection portion,
119a: connecting projection,
119b: connecting projection,
120: tube sealing portion,
120h: drain hole,
120p: flat portion,
120r: groove portion,
210: flat tube,
211: tube wall,
219: connection portion,
310: flat tube,
310a: tube-side wall portion,
310b: tube-side wall portion,
311: tube wall,
315: position-regulation portion,
315a: position-regulation projection,
315b: position-regulation projection,
319: connection portion,
319a: connecting projection,
319b: connecting projection,
Ax: tube axis,
B: plane,
C: plane,
D1: first direction,
D2: second direction,
D3: third direction,
Dia: inner diameter,
Dob: outer diameter,
Lp: tube pitch,
Lr: pitch,
P1a: heat transfer passage,
P1at: turning passage,
P1b: header passage,
P1b1: header passage region,
P1b2: header passage region,
P1c: header passage,
P1d: header passage,
P2: passage,
Sg: hollow portion,
a: first pipe,
b: second pipe,
h1a: through hole,
h1b: through hole,
h2a: through hole

Claims

1. A heat exchanger comprising a plurality of flat tubes arranged in a first direction and extending in a second direction crossing the first direction, wherein

    the flat tubes each include a tube wall having a heat transfer passage in which a fluid flows in an internal space of the heat transfer passage,
    the tube wall includes tube-side wall portions facing each other in the first direction, formed in the shape of a flat plate, and having through holes,
    any adjacent ones of the flat tubes include a connection portion that connects the tube walls of the adjacent flat tubes and causes the heat transfer passages in the tube walls to communicate with each other, and
    the connection portion includes one or more connecting projections formed at an associated one or ones of the tube-side wall portions of the adjacent flat tubes and projecting in the first direction from an associated one or ones of peripheral portions of the through holes.

2. The heat exchanger of claim 1,

    further comprising a tube sealing portion formed in the shape of a plate, provided at least one end of each of the plurality of flat tubes in the second direction, and covering one end of the heat transfer passage of each of the plurality of flat tubes,
    wherein the one ends of the plurality of flat tubes are fixed to the tube sealing portion at a constant pitch.

3. The heat exchanger of claim 1 or 2,
wherein the connection portion includes connecting projections formed at the tube-side wall portions of the adjacent flat tubes, which face each other.

4. The heat exchanger of claim 3,
wherein the connecting projections formed at the tube-side wall portions of the adjacent flat tubes at least overlap each other in the first direction.

5. The heat exchanger of any one of claims 1 to 4,

    wherein each of the flat tubes further includes a first partition that is provided in the internal space of the tube wall, extends in the second direction and that partitions the internal space in a third direction orthogonal to the first direction and the second direction, and
    at least one end of the first partition in the second direction is located inward of both ends of the flat tube in the second direction.

6. The heat exchanger of any one of claims 1 to 5, further comprising a second partition provided between the tube walls of at least one pair of adjacent ones of the plurality of flat tubes to block a flow of the fluid between the heat transfer passages via the connection portion.

7. The heat exchanger of any one of claims 1 to 6, wherein a position-regulation projection is provided

on at least one of the tube-side wall portions of the adjacent flat tubes to regulate a distance between the tube walls.

8. An air-conditioning apparatus comprising
a refrigerant circuit in which a compressor, the heat exchanger of any one of claims 1 to 7, an expansion valve, and an indoor heat exchanger are connected by refrigerant pipes and the fluid circulates.

FIG. 1

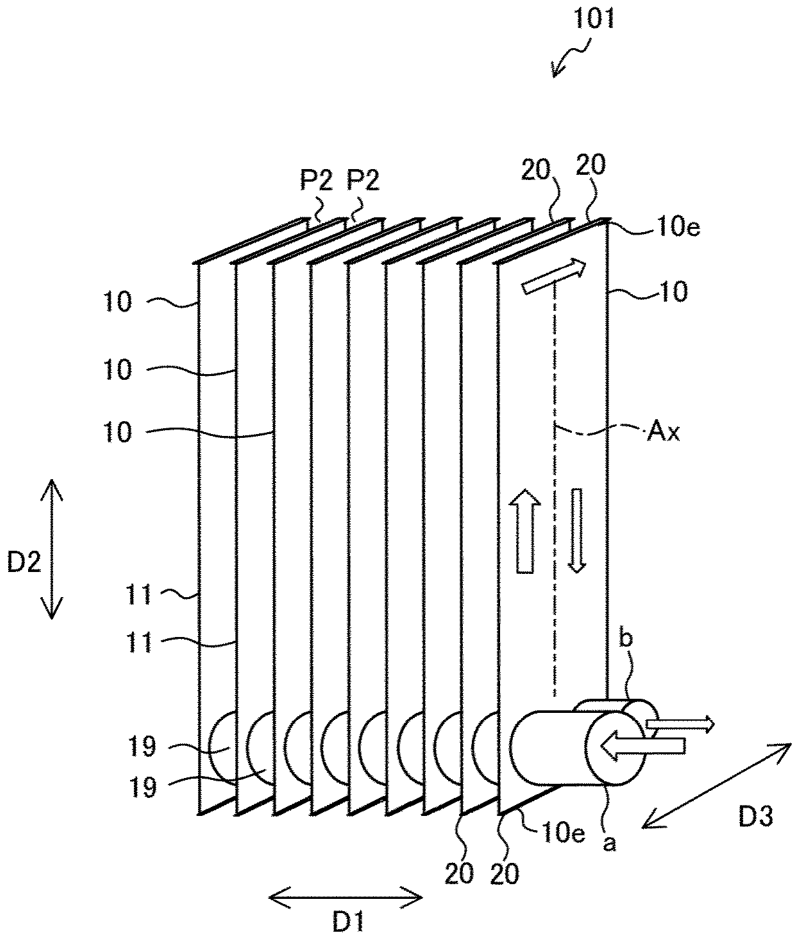


FIG. 2

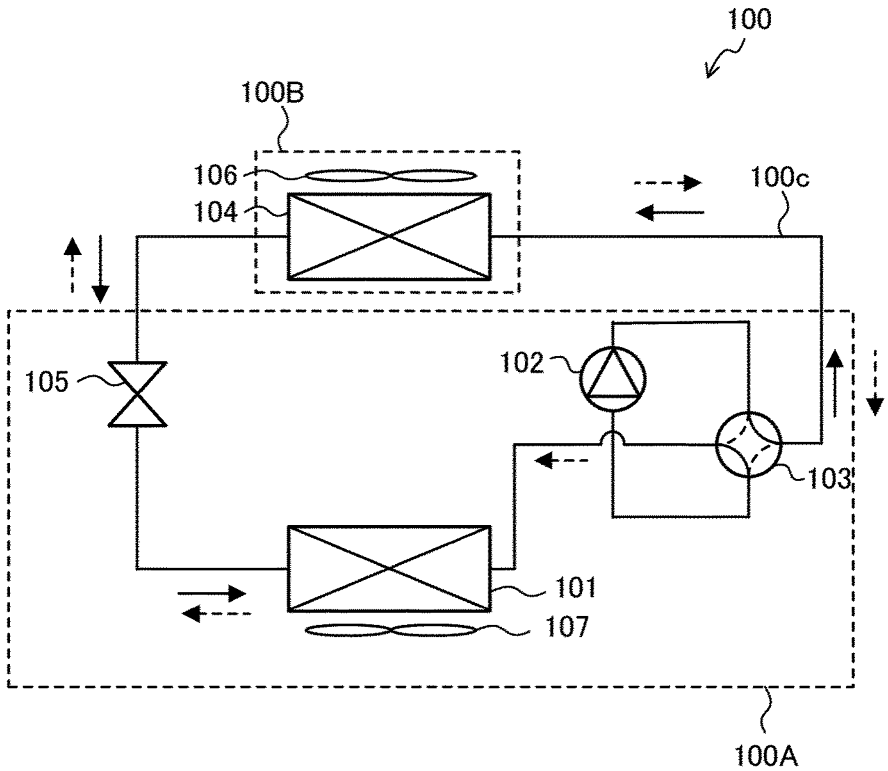
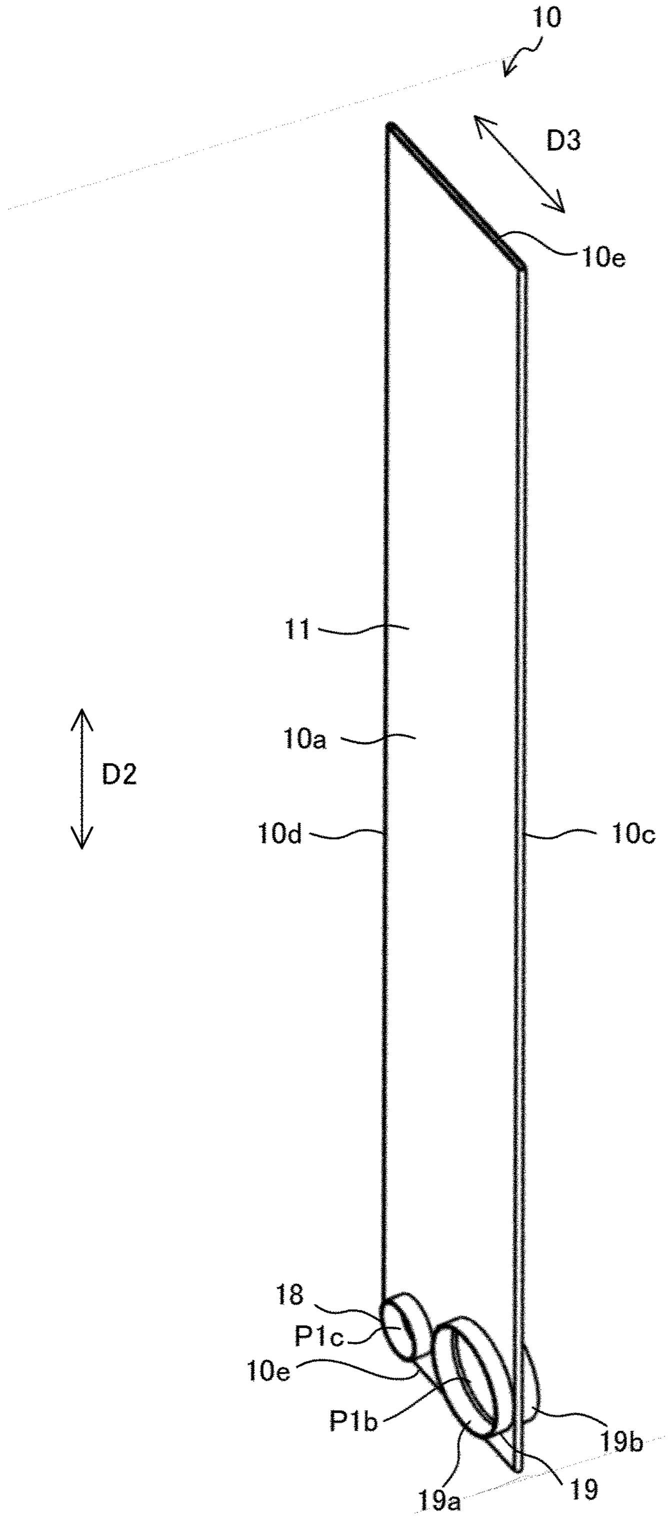


FIG. 3



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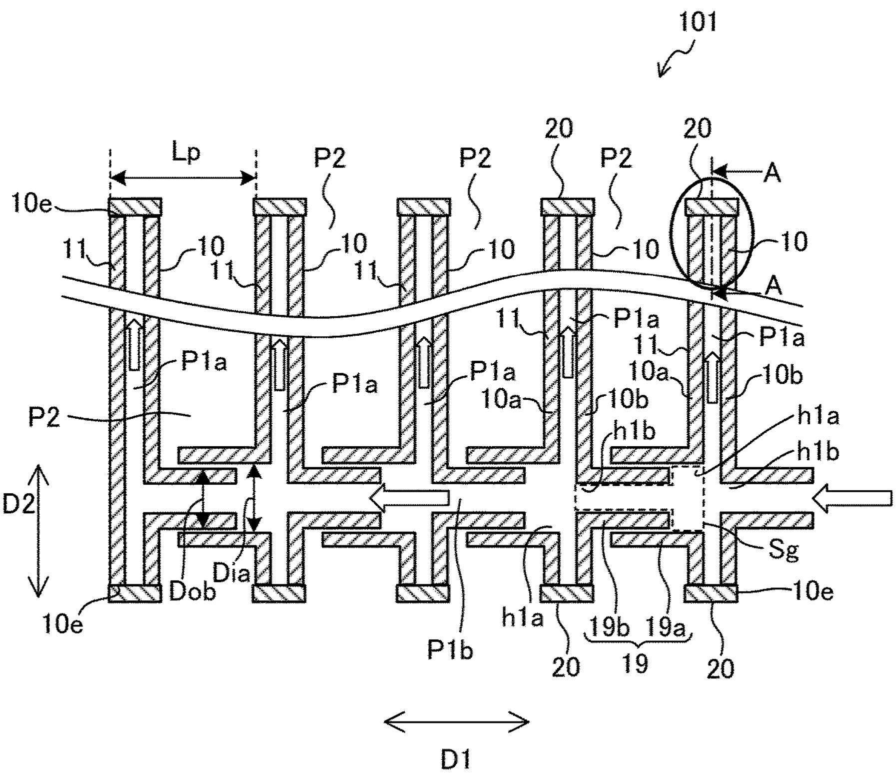
101
Lp
P2
P2
20
P2
20
A
10e
11
10
11
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P1a
11
P1a
P1a
P1a
10a
10b
P2
10a
10b
h1a
h1b
h1b
D2
Sg
Dob
Dia
10e
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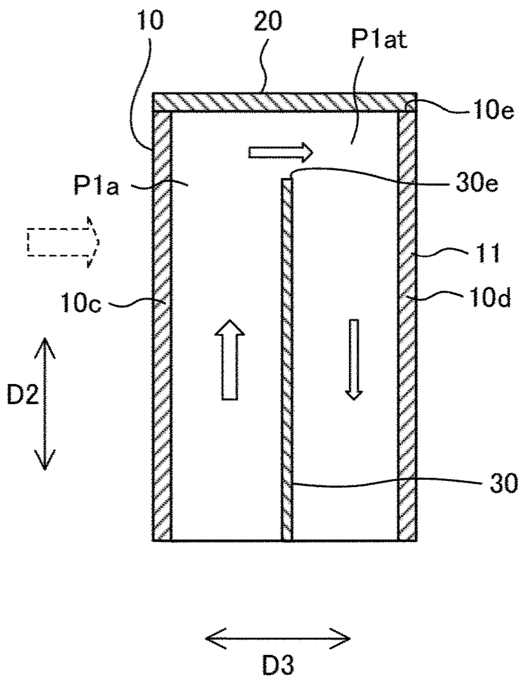
h1a
19b
19a
P1b
20
19
20
D1

FIG. 5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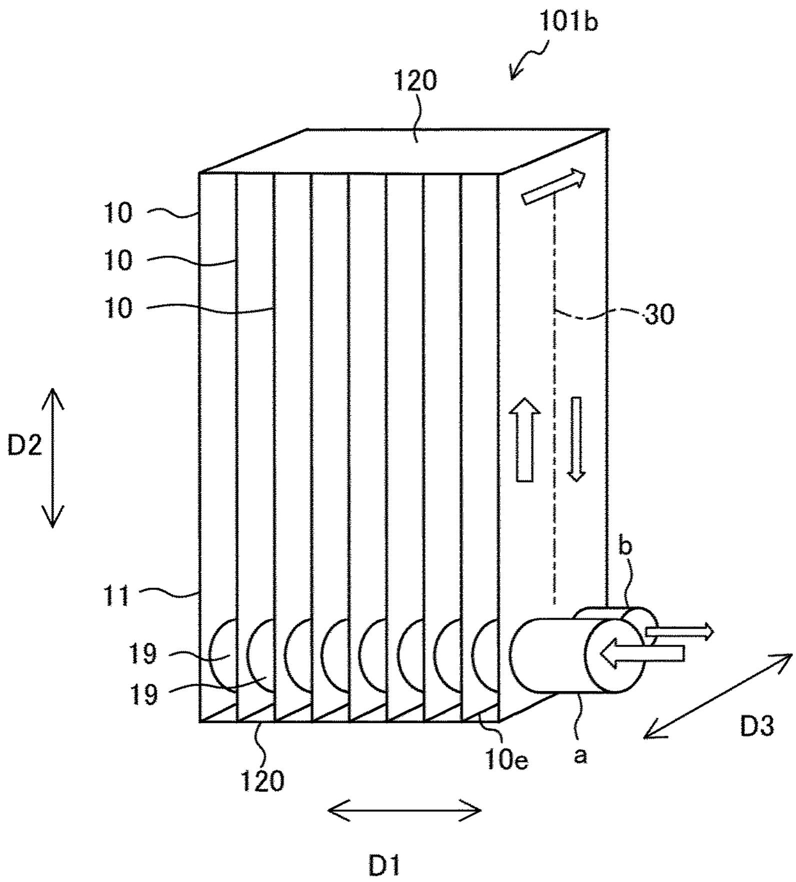
P1a
11
10c
10d
D2
30
D3

FIG. 6



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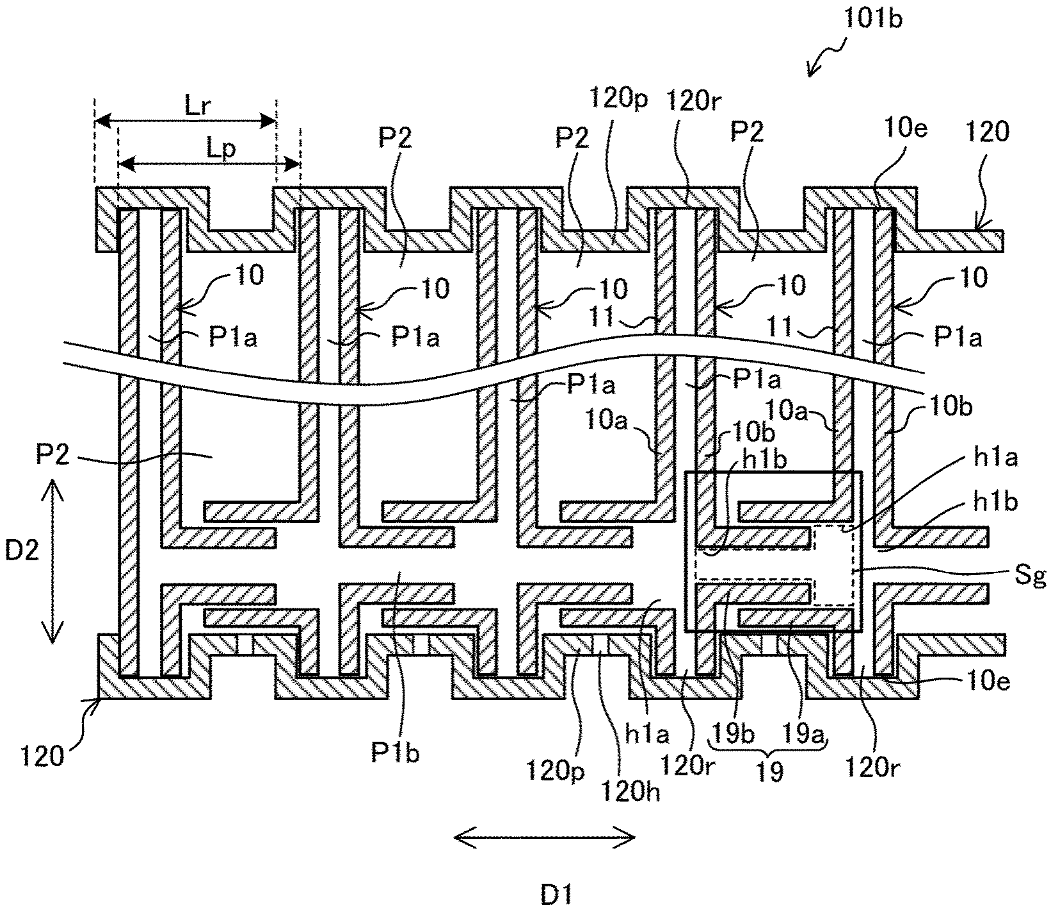
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10a
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h1b
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h1b
P2
D2
Sg
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120h
h1a
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19b
19a
19
120r
D1

FIG. 8

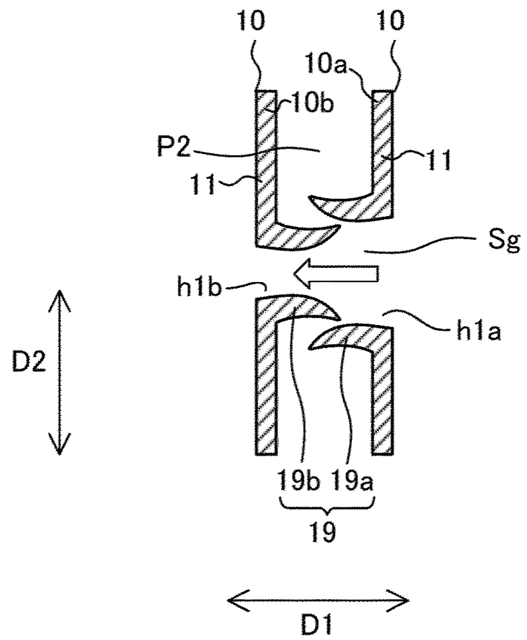


FIG. 9

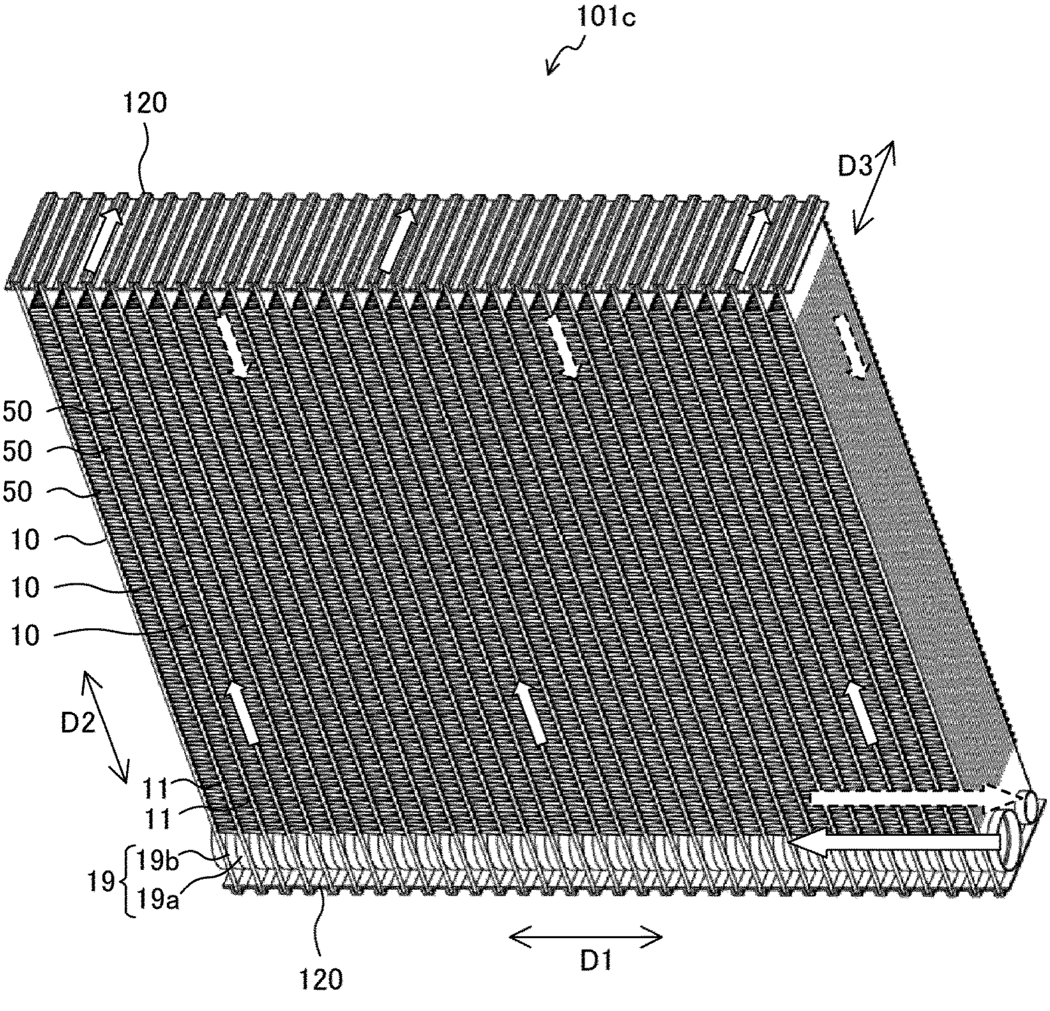
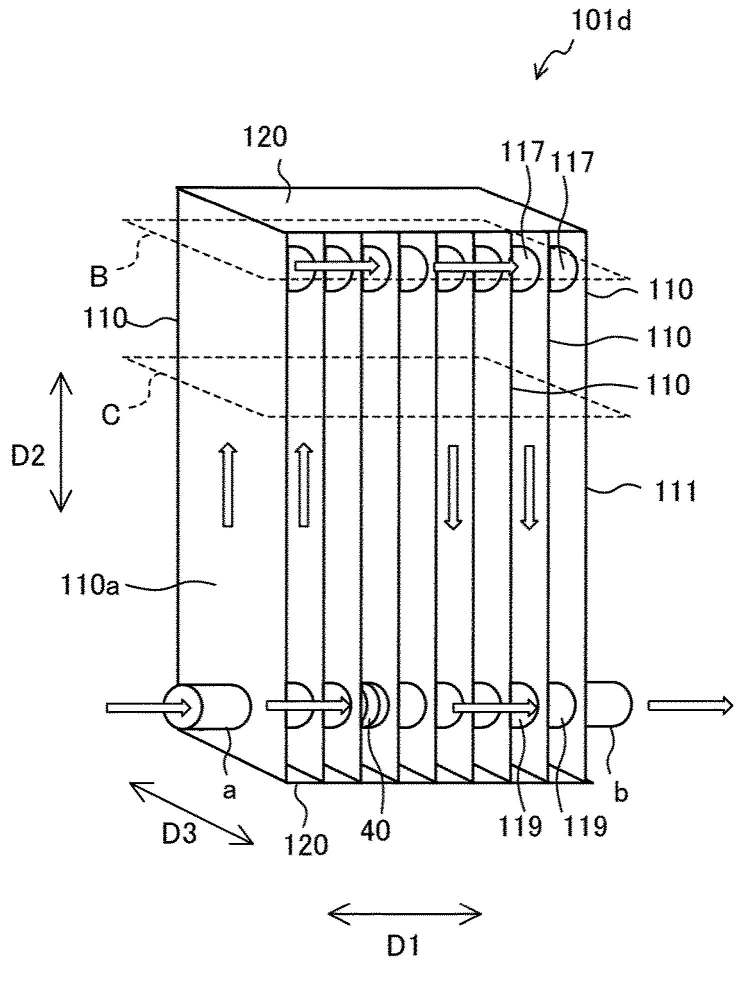


FIG. 10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120
117
117
B
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110
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C
D2
111
110a
a
b
D3
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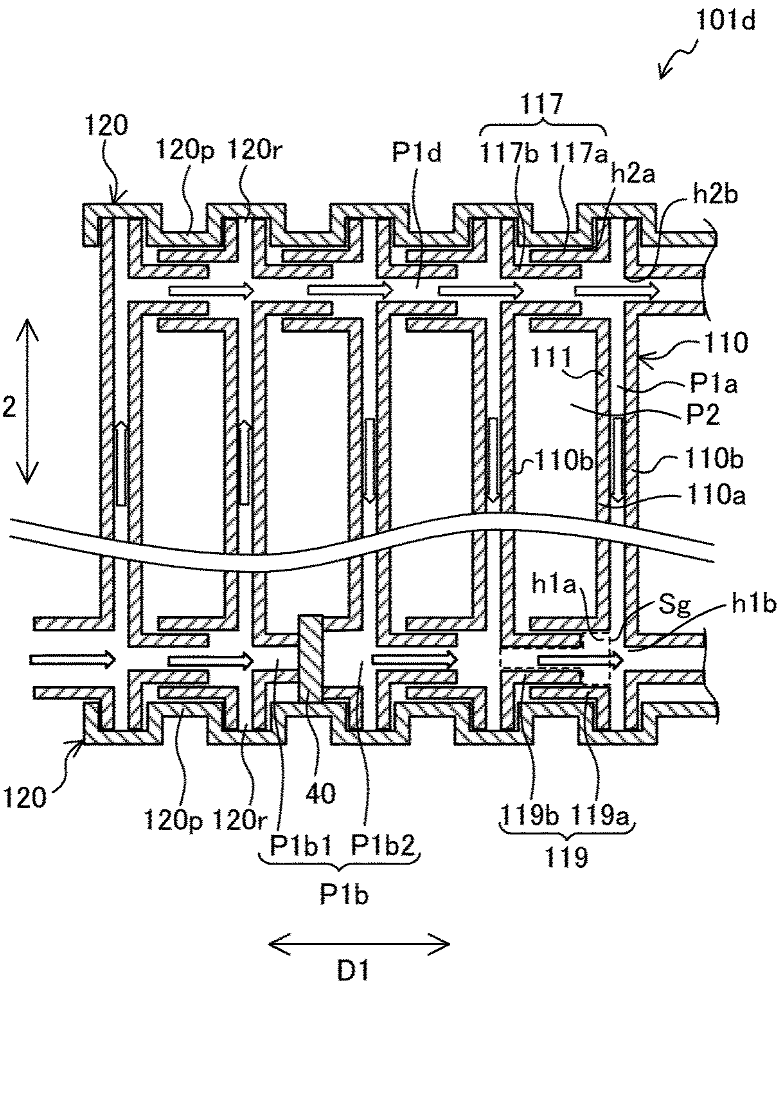
40
119
119
D1

FIG. 11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h2a
h2b
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P1a
P2
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110a
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Sg
h1b
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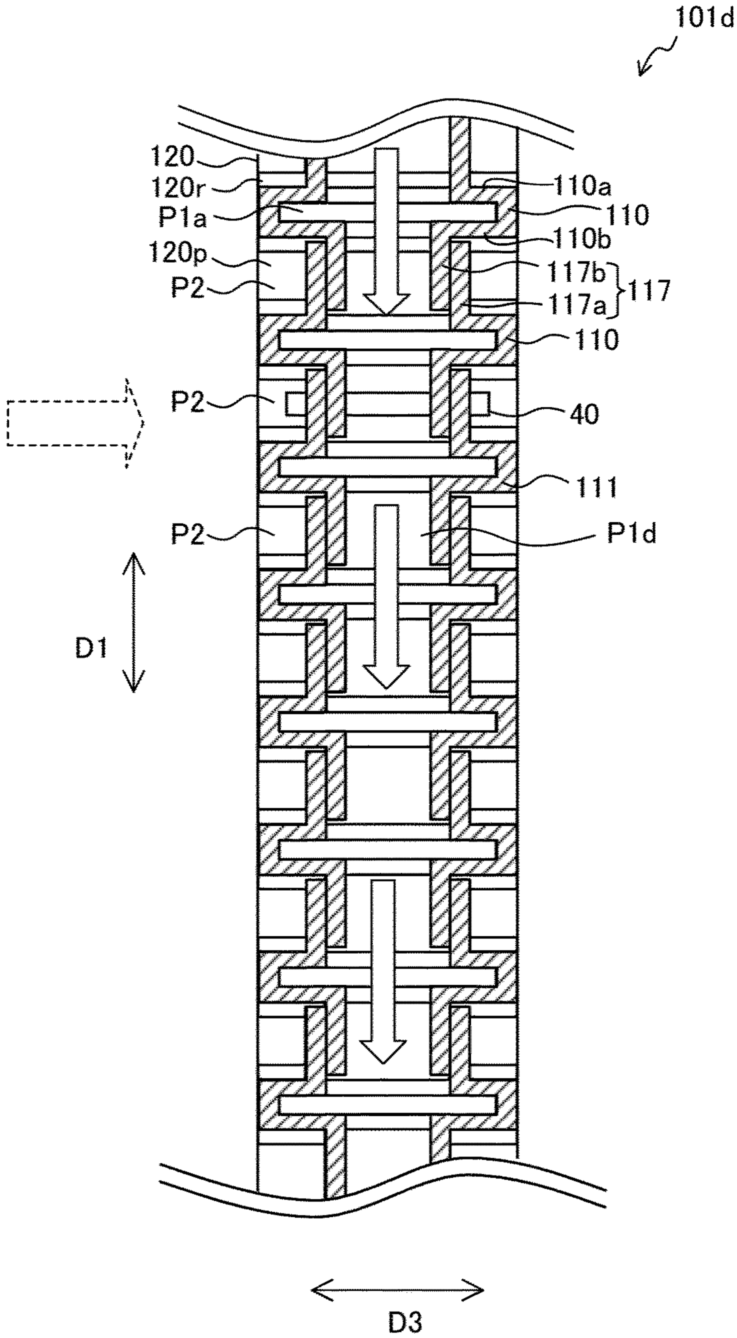
120p 120r
P1b1 P1b2
P1b
119b 119a
119
D1

FIG. 12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P2
P2
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117b
117a
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110
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111
P1d
D1
D3

FIG. 13

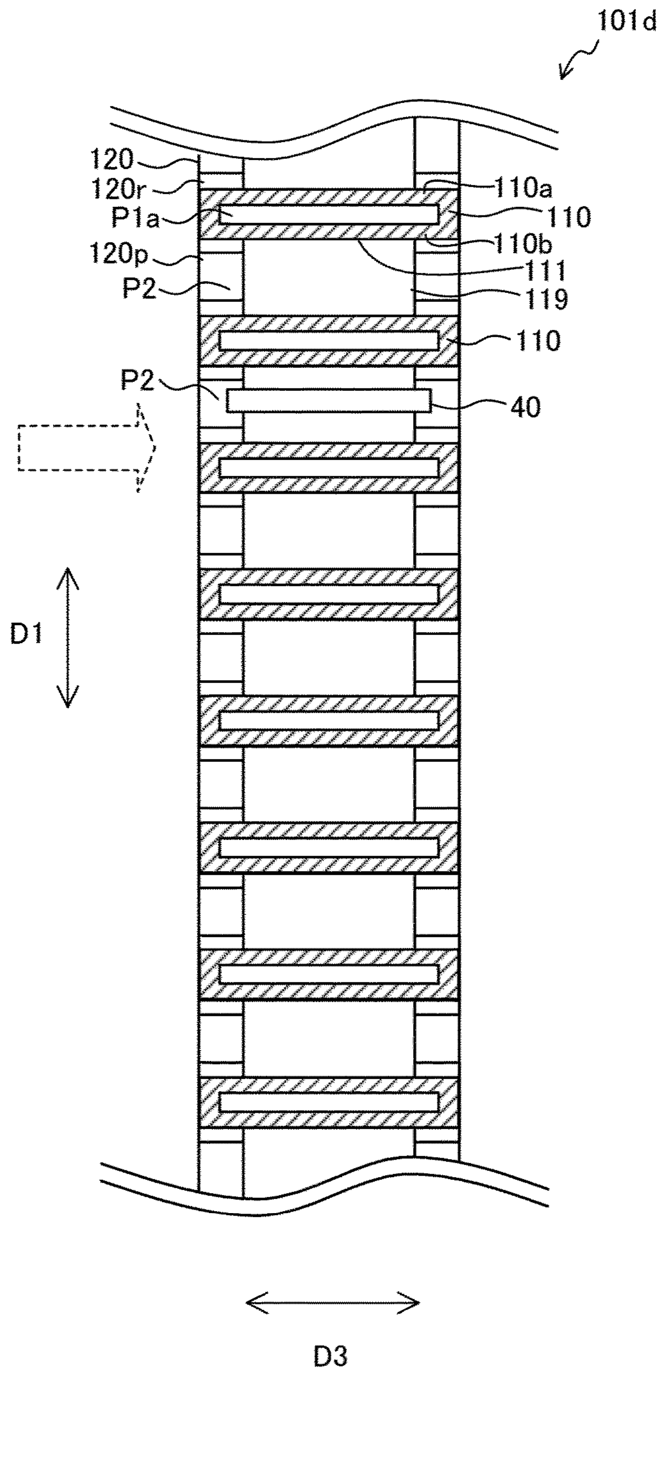
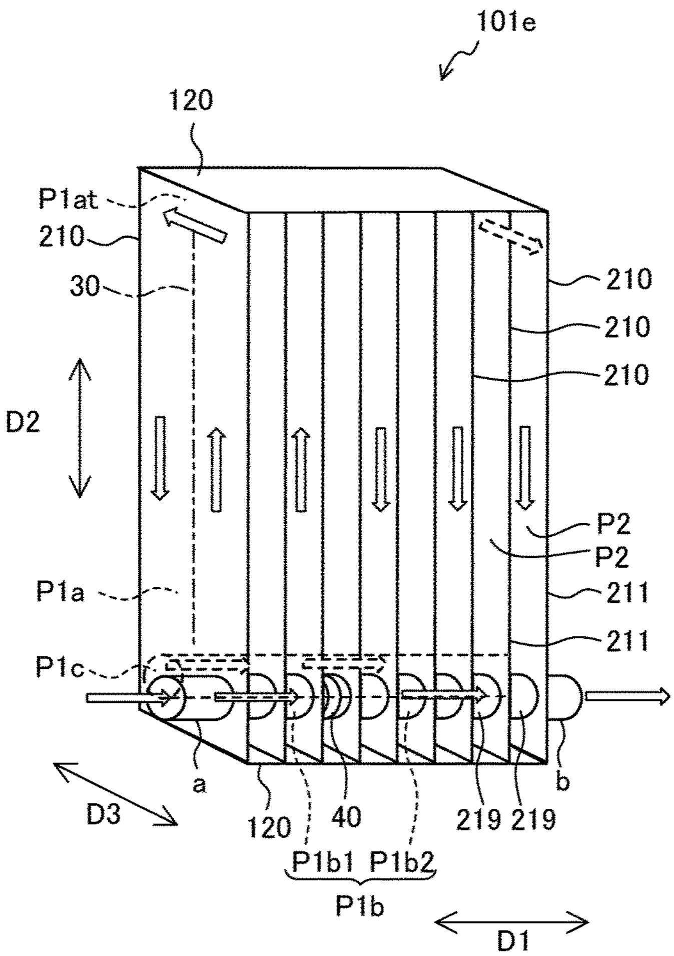


FIG. 14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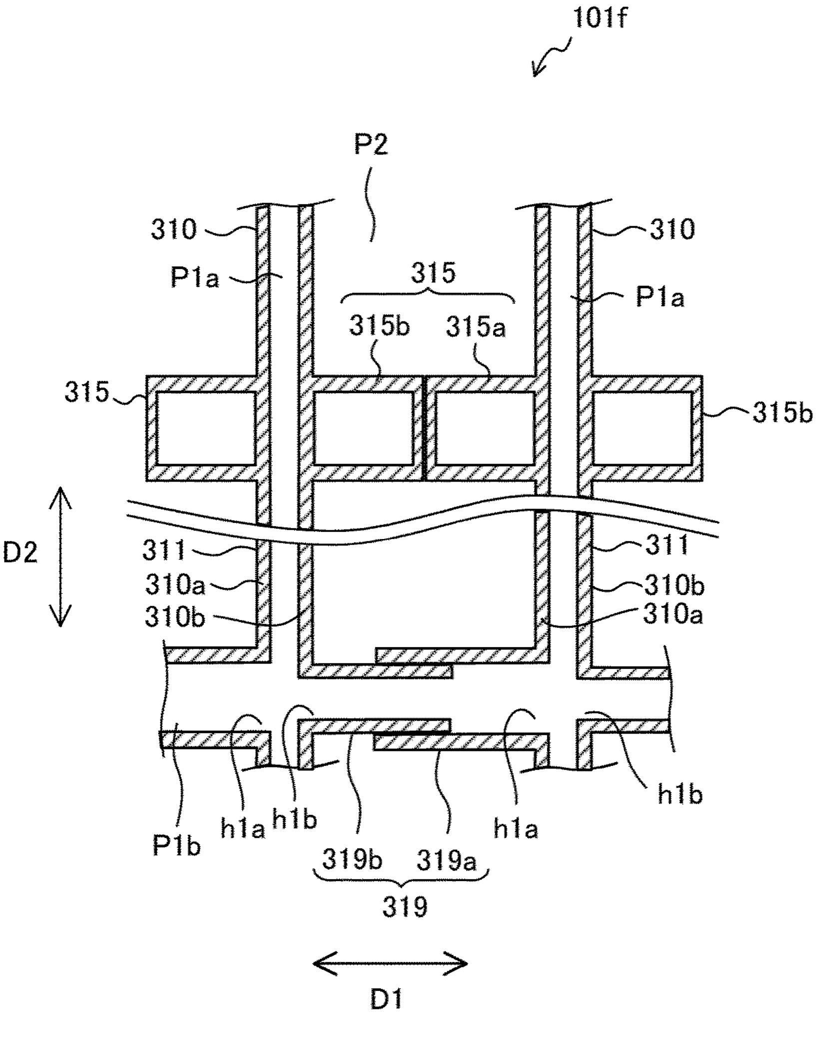
P1at
210
30
D2
P1a
P1c
a
D3
120
40
P1b1
P1b2
P1b
219
219
b
D1
210
210
210
P2
P2
211
211

FIG. 15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P2
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310
P1a
P1a
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315b
315a
315
315b
D2
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310a
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310b
310a
P1b
h1a
h1b
319b
319a
h1a
h1b
319
D1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/010084

A. CLASSIFICATION OF SUBJECT MATTER

F28D 1/053(2006.01)i; ***F28F 1/02***(2006.01)i; ***F28F 3/08***(2006.01)i; ***F28F 9/02***(2006.01)i
FI: F28D1/053 A; F28F3/08 301Z; F28F9/02 301D; F28F1/02 A

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28D1/053; F28F1/02; F28F3/08; F28F9/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 202626/1986 (Laid-open No. 108056/1988) (NIHON RADIATOR CO., LTD.) 12 July 1988 (1988-07-12), specification, page 2, line 6 to page 12, line 11, fig. 1-8	1, 3-8 2
Y	JP 2016-118335 A (KEIHIN THERMAL TECHNOLOGY CORP.) 30 June 2016 (2016-06-30) paragraphs [0001]-[0044], fig. 1-12	1, 3-8
Y	JP 2018-17430 A (HITACHI CHEMICAL COMPANY, LTD.) 01 February 2018 (2018-02-01) paragraphs [0017]-[0025], fig. 3-4	7-8
A	JP 2007-053307 A (DENSO CORPORATION) 01 March 2007 (2007-03-01) paragraphs [0001]-[0107], fig. 1-21	1-8
A	JP 2012-107804 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 07 June 2012 (2012-06-07) paragraphs [0001]-[0084], fig. 1-9	1-8

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2023	**16 May 2023**
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/JP2023/010084**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 3199792 U (WAKI FACTORY INC.) 10 September 2015 (2015-09-10) paragraphs [0001]-[0037], fig. 1-10	1-8

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/010084

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 63-108056 U1	12 July 1988	(Family: none)	
JP 2016-118335 A	30 June 2016	(Family: none)	
JP 2018-17430 A	01 February 2018	(Family: none)	
JP 2007-053307 A	01 March 2007	US 2007/0039717 A1 paragraphs [0002]-[0139] DE 102006038463 A	
JP 2012-107804 A	07 June 2012	US 2013/0220987 A1 paragraphs [0001]-[0114], fig. 1-9 WO 2012/067157 A1 EP 2642234 A1 CN 103201584 A	
JP 3199792 U	10 September 2015	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

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- JP 2020176791 A **[0004]**