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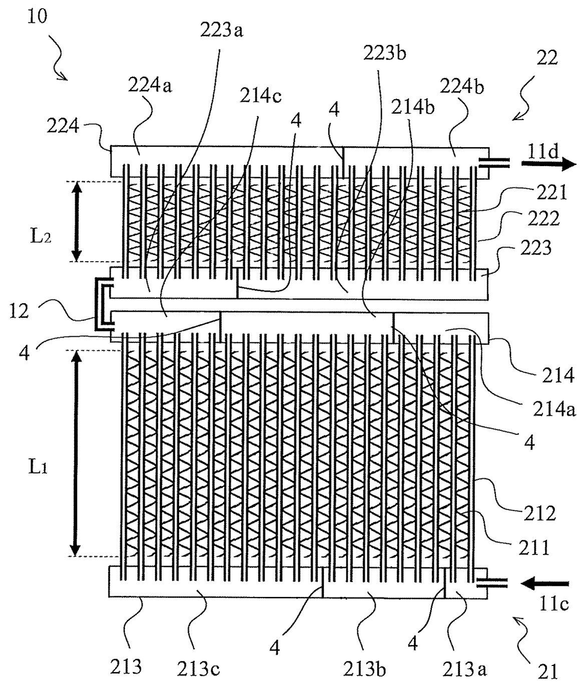
(54) AIR CONDITIONING DEVICE

(57) In an air-conditioning apparatus (200) including a heat exchanger (10) configured to switch between serving as an evaporator and serving as a condenser, the heat exchanger (10) includes a first heat exchanger (21), a second heat exchanger (22), and a connection pipe (12). The first heat exchanger (213) includes a first header (21) divided into a plurality of chambers and connected with one end of each of the first heat transfer tubes (212), and a second header (214) extending in a horizontal direction and connected with the other end of each of the first heat transfer tubes (212). The second heat exchanger (22) includes a plurality of second heat transfer tubes (222), a third header (223) extending in the horizontal direction and connected with one end of each of the second heat transfer tubes (222), and a fourth header (224) extending in the horizontal direction and connected with the other end of each of the second heat transfer tubes (222). The connection pipe (12) connects the first heat exchanger (21) and the second heat exchanger (22). The first heat transfer tubes (212) each have a length greater than the length of each of the second heat transfer tubes (222).

FIG. 2



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Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus including a heat exchanger capable of serving both as a condenser and as an evaporator.

Background Art

[0002] For air-conditioning apparatuses, it is known to use a heat exchanger including heat transfer tubes in the form of flat tubes with a flat cross-section to allow heat exchange between refrigerant flowing inside the flat tubes and fluid present outside the flat tubes. For example, Patent Literature 1 discloses a heat exchanger that serves as a condenser for an air-conditioning apparatus. In the heat exchanger, opposite ends of a plurality of flat tubes are connected to a pair of headers extending in the horizontal direction. The interior of each header is divided by a partition plate into parts such that refrigerant flows through the flat tubes in a meandering manner.

[0003] Patent Literature 1 proposes sequentially reducing the number of flat tubes from the inlet to the outlet so that the heat exchanger has a smaller channel cross-sectional area in a downstream portion of the heat exchanger with respect to the refrigerant flow than in an upstream portion with respect to the refrigerant flow. This helps to enhance the flow velocity of refrigerant in the downstream portion to mitigate a decrease in heat transfer coefficient, and consequently maintain high heat exchange performance.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication .
JP 2015- 230 129 A

Summary of Invention

Technical Problem

[0005] When an air-conditioning apparatus capable of switching between cooling and heating operations switches from one operation to another, a heat exchanger serving as a condenser switches to serving also as an evaporator. A heat exchanger employing flat tubes as disclosed in Patent Literature 1 is suited for reducing the amount of refrigerant, that is, suited for so-called refrigerant saving. When the heat exchanger disclosed in Patent Literature 1 serves as an evaporator, however, the channel cross-sectional area is smaller in a portion of the heat exchanger where refrigerant enters than in a portion of the heat exchanger where refrigerant exits. This may result in increased refrigerant pressure loss across the entire channel length. Increased refrigerant pressure loss leads to decreased saturation temperature of refrigerant, and consequently decreased air-conditioning performance.

[0006] It is accordingly an object of the present invention to provide an air-conditioning apparatus including a heat exchanger capable of achieving both refrigerant saving and improved performance.

[0007] An air-conditioning apparatus according to an embodiment of the present invention is an air-conditioning apparatus in which a compressor, a condenser, a pressure reducing device, and an evaporator are connected by a pipe and in which refrigerant circulates.

[0008] The air-conditioning apparatus includes a heat exchanger, and a fan. The heat exchanger is configured to, in response to switching of directions of refrigerant flow, switch between serving as the evaporator and serving as the condenser. The fan is configured to generate an air flow to send air to the heat exchanger.

[0009] The heat exchanger includes a first heat exchanger, a second heat exchanger, and a connection pipe.

[0010] The first heat exchanger includes a plurality of first heat transfer tubes, a first header, and a second header. The first header extends in a horizontal direction, and has an internal space divided into a plurality of chambers including a first chamber and a second chamber. The first header is connected with one end of each of the plurality of first heat transfer tubes. The second header extends in the horizontal direction, and is connected with an other end of each of the plurality of first heat transfer tubes.

[0011] The second heat exchanger includes a plurality of second heat transfer tubes, a third header, and a fourth header. The third header extends in the horizontal direction, and is connected with one end of each of the plurality of second heat transfer tubes. The fourth header extends in the horizontal direction, and is connected with an other end of each of the plurality of second heat transfer tubes.

[0012] The connection pipe connects one of the first header and the second header of the first heat exchanger, and the third header of the second heat exchanger.

[0013] For an operation in which the heat exchanger is made to serve as the evaporator:

the plurality of first heat transfer tubes are connected such that, after refrigerant to be evaporated enters the first chamber of the first header from the pipe, the refrigerant flows to the second header, and then flows from the second header to the second chamber of the first header;

the plurality of second heat transfer tubes are connected such that, after the refrigerant passes through the first heat exchanger, the refrigerant flows via the connection pipe into the third header of the second heat exchanger, and then flows from the third header to the fourth header; and further,

the pipe is connected such that, after the refrigerant passes through the second heat exchanger, the refrigerant is sucked into the compressor.

[0014] For an operation in which the heat exchanger is made to serve as the condenser, the pipe is connected such that, after refrigerant to be condensed passes through the second heat exchanger from the pipe, the refrigerant flows via the connection pipe into one of the plurality of chambers of the first header of the first heat exchanger, or into the second header, and after passing through the first heat exchanger, the refrigerant exits from the first chamber of the first header.

[0015] The plurality of first heat transfer tubes each have a length greater than a length of each of the plurality of second heat transfer tubes.

Advantageous Effects of Invention

[0016] The air-conditioning apparatus according to an embodiment of the present invention makes it possible to achieve both enhanced performance and refrigerant saving, by enabling reduction of pressure loss during an operation in which the first heat exchanger and the second heat exchanger are each made to serve as an evaporator, and enabling reduction of refrigerant density during an operation in which the first heat exchanger and the second heat exchanger are each made to serve as a condenser.

Brief Description of Drawings

[0017]

FIG. 1 is a diagram illustrating the configuration of an air-conditioning apparatus according to Embodiment 1.

FIG. 2 is a diagram of an indoor heat exchanger disposed in an air-conditioning apparatus according to Embodiment 1.

FIG. 3 is a diagram illustrating an air-conditioning apparatus including an indoor heat exchanger according to Embodiment 1.

FIG. 4 illustrates the relationship between the evaporator performance of an indoor heat exchanger, and heat-transfer-tube length ratio according to Embodiment 1.

FIG. 5 is a diagram of an air-conditioning apparatus including an indoor heat exchanger according to Embodiment 1.

FIG. 6 illustrates the relationship between the amount of refrigerant within an indoor heat exchanger, and heat-transfer-tube length ratio according to Embodiment 1.

FIG. 7 is a diagram of an indoor heat exchanger according to a first modification of Embodiment 1.

FIG. 8 is a diagram of an indoor heat exchanger according to a second modification of Embodiment 1.

FIG. 9 is a diagram illustrating an indoor unit according to Embodiment 2.

FIG. 10 is a diagram illustrating the flow of refrigerant through a connection pipe of the indoor heat exchanger illustrated in FIG. 9.

FIG. 11 is a perspective view of an indoor unit, illustrating the internal structure of the indoor unit according to Embodiment 3.

FIG. 12 is a diagram of an A-A cross-section of the indoor unit illustrated in FIG. 11.

FIG. 13 is a diagram of an A-A cross-section of an indoor unit according to a comparative example.

FIG. 14 is a diagram for explaining the relationship between an indoor fan of an indoor unit, and air velocity according to Embodiment 3.

FIG. 15 illustrates the relationship between position in the rotation axis direction of the indoor fan illustrated in FIG. 14, and air velocity, and the relationship between position in the circumferential direction of the rotation axis of the indoor fan, and air velocity.

FIG. 16 is a diagram illustrating the configuration of refrigerant channels in an indoor heat exchanger according to Embodiment 3.

FIG. 17 is a characteristic diagram illustrating an improvement effect with respect to the configuration of refrigerant channels according to Embodiment 3.

FIG. 18 is a perspective view of an indoor unit according to Embodiment 4.

FIG. 19 is a diagram of a B-B cross-section of the indoor unit illustrated in FIG. 18.

FIG. 20 is a diagram illustrating the flow velocity distribution of an air flow through the indoor unit illustrated in FIG. 19.

IG. 21 is a diagram illustrating a schematic cross-section of an indoor unit according to Embodiment 5.

FIG. 22 is a cross-sectional diagram illustrating a schematic A-A cross-section of an indoor unit 202 according to Embodiment 5.

Description of Embodiments

[0018] Embodiments of an air-conditioning apparatus according to the present invention are described below. The particular details illustrated in the drawings are intended to be illustrative only, and not to limit the present invention. Elements designated by the same reference signs in the drawings represent the same or corresponding Elements throughout the specification. Further, in the drawings below, the relative sizes of various components are not necessarily drawn to scale.

Embodiment 1

<Configuration of Air-Conditioning Apparatus 200>

[0019] FIG. 1 is a diagram illustrating the configuration of an air-conditioning apparatus 200 according to Embodiment 1. The air-conditioning apparatus 200 is a heat pump apparatus including a circuit in which refrigerant circulates, and designed to transfer heat through a refrigeration cycle in which refrigerant undergoes compression, condensation, expansion, and evaporation within the circuit. In such a heat pump apparatus, a compressor, a condenser, a pressure reducing device such as an expansion device, and an evaporator are connected by a pipe, and refrigerant circulates. As illustrated in FIG. 1, the air-conditioning apparatus 200 according to Embodiment 1 includes an outdoor unit 201, and an indoor unit 202. The air-conditioning apparatus 200 is capable of performing a cooling operation and a heating operation through switching of the directions of refrigerant flow.

[0020] The outdoor unit 201 is provided with the following components: an outdoor fan 13a, a compressor 14, a four-way valve 15, an outdoor heat exchanger 16, and an expansion device 17. The indoor unit 202 is provided with an indoor heat exchanger 10, and an indoor fan 13b. The indoor heat exchanger 10 includes a first heat exchanger 21, and a second heat exchanger 22. The indoor heat exchanger 10 is a heat exchanger that allows heat exchange between the temperature of indoor air and the temperature of refrigerant. The indoor fan 13b is a fan that generates an air flow such that indoor air is sent to the indoor heat exchanger 10. The outdoor unit 201 is an example of a heat-source-side heat exchanger. The indoor unit 202 is an example of a use-side heat exchanger.

[0021] The four-way valve 15 and the outdoor heat exchanger 16 are connected by a pipe 11a. The outdoor heat exchanger 16 and the expansion device 17 are connected by a pipe 11b. The expansion device 17, and the first heat exchanger 21 of the indoor heat exchanger 10 are connected by a pipe 11c. The expansion device 17 is a pressure reducing device that, by reducing the cross-sectional area through which refrigerant passes, causes the pressure of refrigerant to decrease after passage through the cross-sectional area relative to the pressure of refrigerant before passage through the cross-sectional area. The second heat exchanger 22 of the indoor heat exchanger 10, and the four-way valve 15 are connected by a pipe 11d.

[0022] A refrigeration cycle is formed as refrigerant flows through the compressor 14, the four-way valve 15, the outdoor heat exchanger 16, the expansion device 17, and the indoor heat exchanger 10. The four-way valve 15 is a switching valve that switches the directions of refrigerant flow discharged from the compressor 14. The four-way valve 15 switches the directions of refrigerant flow, such that refrigerant is either routed through the pipe 11a toward the outdoor heat exchanger 16 or routed through the pipe 11d toward the indoor heat exchanger 10. Switching between cooling and heating operations of the air-conditioning apparatus 200 is performed by switching of the directions of refrigerant flow by the four-way valve 15. The switching valve may be implemented not by the four-way valve 15 but instead by a combination of, for example, other valves or pipes, such as a combination of a plurality of two-way valves.

[0023] During cooling operation of the air-conditioning apparatus 200, the indoor heat exchanger 10 serves as an evaporator, and the outdoor heat exchanger 16 serves as a condenser. During heating operation, the indoor heat exchanger 10 serves as a condenser, and the outdoor heat exchanger 16 serves as an evaporator. That is, the air-conditioning apparatus 200 includes heat exchangers that, in response to reversing of the direction of refrigerant flow, switch between serving as an evaporator and serving as a condenser.

<Configuration of Indoor Heat Exchanger 10>

[0024] FIG. 2 is a diagram of the indoor heat exchanger 10 disposed in the air-conditioning apparatus 200 according to Embodiment 1. As illustrated in FIG. 2, the indoor heat exchanger 10 includes the first heat exchanger 21, the second heat exchanger 22, and a connection pipe 12 that connects the first heat exchanger 21 and the second heat exchanger 22.

[0025] The first heat exchanger 21 includes a plurality of first heat transfer tubes 212, a plurality of first fins 211, a first header 213, and a second header 214. The second heat exchanger 22 includes a plurality of second heat transfer tubes 222, a plurality of second fins 221, a third header 223, and a fourth header 224. The first heat exchanger 21 and the second heat exchanger 22 are connected by the connection pipe 12. Each of the first heat transfer tube 212 and the second heat transfer tube 222 is a heat transfer tube in which refrigerant passes for heat exchange with ambient air present outside the heat transfer tube. The first heat transfer tube 212 and the second heat transfer tube 222 are each arranged with a spacing from an adjacent heat transfer tube such that air passes through the spacing. The first header 213, the second header 214, the third header 223, and the fourth header 224 either distribute refrigerant to, or collect refrigerant from, a plurality of heat transfer tubes such as the first heat transfer tubes 212 or the second heat transfer tubes 222. One of the first header 213 and the second header 214 of the first heat exchanger 21, or one of the third header 223 and the fourth header 224 of the second heat exchanger 22 is connected with a pipe through which refrigerant enters or exits.

[0026] The connection pipe 12 connects the first heat exchanger 21 and the second heat exchanger 22 in series with each other. That is, after refrigerant passes through one of the first heat exchanger 21 and the second heat exchanger 22, the refrigerant flows into the other heat exchanger through the connection pipe 12. When the first heat exchanger 21 and the second heat exchanger 22 each serve as an evaporator, refrigerant including a liquid phase flows into the second heat exchanger 22 after passing through the first heat exchanger 21 and the connection pipe 12. When the first heat exchanger 21 and the second heat exchanger 22 each serve as a condenser, refrigerant including a gas phase flows into the first heat exchanger 21 after passing through the second heat exchanger 22 and the connection pipe 12. With the first heat exchanger 21 and the second heat exchanger 22 each serving as an evaporator, the header to which a pipe is connected to allow entry of refrigerant including a liquid phase into the first heat exchanger 21 is the first header 213, and the header to which the connection pipe 12 is connected to allow entry of refrigerant into the second heat exchanger 22 is the third header 223. At this time, refrigerant flows into the second heat exchanger 22 from the connection pipe 12 connected to the second header 214 of the first heat exchanger 21, and refrigerant exits to the outside from the fourth header 224 of the second heat exchanger 22. The configuration to be employed in this case, however, is not limited to the configuration mentioned above. In an alternative configuration, refrigerant may flow into the second heat exchanger 22 from the connection pipe 12 connected to the first header 213 of the first heat exchanger 21, or refrigerant may exit to the outside from the third header 223 of the second heat exchanger 22.

[0027] The first heat transfer tubes 212 of the first heat exchanger 21 are flat tubes, and stacked in alternation with the first fins 211. The first fins 211 are, for example, corrugated fins. Each flat tube has, when viewed in a cross-section perpendicular to a direction in which the flat tube extends, a flattened shape elongated in one direction. Air-conditioning apparatuses in which high-pressure refrigerant flows typically employ multi-hole tubes with their internal channel divided into a plurality of parts in the longitudinal direction. Corrugated fins are pieces of sheet metal with good thermal conductivity such as aluminum formed into corrugations. The first fin 211 and the second fin 221 serve to increase the heat exchange area of the first heat exchanger 21 for improved heat exchange between each heat transfer tube and air passing around each flat tube. The first heat transfer tubes 212 are arranged in parallel in the longitudinal direction with a spacing therebetween in the lateral direction. The apexes of the corrugations of the corrugated fins are joined to surfaces of the flat tubes that face each other with the spacing therebetween.

[0028] The first header 213 and the second header 214 of the first heat exchanger 21 extend in the horizontal direction. The first header 213 is connected with one end of the first heat transfer tubes 212, and the second header 214 is connected with the other end of the first heat transfer tubes 212. The first header 213 and the second header 214 each have a tubular structure with an internal channel cross-sectional area greater than the internal channel cross-sectional area of each first heat transfer tube 212. The first heat transfer tubes 212 each extend in the up-down direction, and are disposed side by side with a horizontal spacing therebetween.

[0029] The first heat exchanger 21 and the second heat exchanger 22 are positioned such that the two heat changers are not in upstream or downstream relation to each other with respect to the flow of air sent from the indoor fan 13b or other components. In other words, the first heat exchanger 21 and the second heat exchanger 22 are positioned in offset relation to each other as viewed from the fan or from an upstream location in the path of the air to be sent. Typically, one of the first header 213 and the second header 214 is positioned proximate to one of the third header 223 and the fourth header 224, and the other one of the first header 213 and the second header 214 is positioned remote from the other one of the third header 223 and the fourth header 224.

[0030] The second heat transfer tubes 222 of the second heat exchanger 22 are flat tubes, and stacked in alternation with the second fins 221. The second fins 221 are, for example, corrugated fins. As with the first fins 211, the second fins 221 serve to increase the heat exchange area of the second heat exchanger 22. One or both of the first heat exchanger 21 and the second heat exchanger 22 may employ plate fins or other fins instead of corrugated fins.

[0031] The third header 223 and the fourth header 224 of the second heat exchanger 22 extend in the horizontal direction. The third header 223 is connected with one end of the second heat transfer tubes 222, and the fourth header 224 is connected with the other end of the second heat transfer tubes 222. The third header 223 and the fourth header 224 each have a tubular structure with an internal channel cross-sectional area greater than the internal channel cross-sectional area of each second heat transfer tube 222. The second heat exchanger 22 and the first heat exchanger 21 are substantially similar in structure, but differ in Elements such as the length of their heat transfer tubes and the internal structure of their headers. The second heat transfer tubes 222 each extend in the up-down direction, and are disposed side by side with a horizontal spacing therebetween. In FIG. 1, the first heat transfer tubes 212 and the second heat transfer tubes 222 are each depicted as lying in a plane. However, the first heat transfer tube 212 and the second heat transfer tube 222 do not necessarily extend in the vertical direction. In an alternative configuration, at least one of the first heat transfer tube 212 and the second heat transfer tube 222 may extend in an oblique direction, or the first heat transfer tube 212 and the second heat transfer tube 222 may extend at an angle relative to each other.

[0032] The internal space of the first header 213 is divided by partition parts 4 into a plurality of chambers including a first chamber 213a and a second chamber 213b. In the following description, each space divided off by the partition part 4 is referred to as chamber, and when reference is made individually to chambers into which each header is divided, such chambers are referred to as first chamber, second chamber, and so on. In the example illustrated in FIG. 2, the first header 213 is divided into three chambers including first to third chambers 213a to 213c. In the example illustrated in FIG. 2, the internal space of the second header 214 is divided by the partition parts 4 into a plurality of chambers including first to third chambers 214a to 214c.

[0033] The internal space of the third header 223 is divided by the partition part 4 into a first chamber 223a and a second chamber 223b. The fourth header 224 is divided by the partition part 4 into a first chamber 224a and a second chamber 224b. In the example mentioned above, all of the headers have an internal space divided into a plurality of chambers by the partition part 4. Alternatively, some of the headers may have an internal space defined as a single chamber without being divided. The number of chambers into which the first header 213 is divided, and the number of chambers into which the second header 214 is divided may be different. The number of chambers into which the third header 223 is divided, and the number of chambers into which the fourth header 224 is divided may be different.

[0034] The connection pipe 12 connects one of the first header 213 and the second header 214 of the first heat exchanger 21, and the third header 223 of the second heat exchanger 22. In the example illustrated in FIG. 2, the connection pipe 12 connects a fourth chamber 213d of the first header 213, and the first chamber 223a of the third header 223. In the example illustrated in FIG. 2, the fourth chamber 213d of the first header 213 and the first chamber 223a of the third header 223, which are connected by the connection pipe 12, are respectively disposed in an end portion of the first header 213 and an end portion of the third header 223 that are located at the same side in the horizontal direction.

[0035] If the connection pipe 12 connects respective chambers of two headers that are located in the same end portion of the two headers as described above, such a configuration makes it possible to reduce the length of the connection pipe 12. FIG. 2 depicts a configuration in which the first heat exchanger 21 and the second heat exchanger 22 are respectively connected with the pipes 11c and 11d such that refrigerant enters or exits each of the heat exchangers from one side of the heat exchanger in the horizontal direction, and in which the connection pipe 12 connects respective chambers of two headers that are located in an end portion of the two headers that is opposite from the one side in the horizontal direction.

[0036] The first chamber 213a of the first header 213 is a chamber located at one end of the first header 213 in the horizontal direction. The connection pipe 12 connects, with the third header 223, one of the chambers of the first header 213 that is located at the other end in the horizontal direction, or one of the chambers of the second header 214 that is located at the other end in the horizontal direction. The above-mentioned configuration allows for reduced length of the connection pipe 12. In an alternative configuration, the connection pipe 12, or the pipes 11c and 11d may be connected to chambers each located in an end portion opposite from the one side in the horizontal direction. In another alternative configuration, the connection pipe 12 may be connected to one of the chambers of the third header 223.

[0037] During an operation in which the indoor heat exchanger 10 is made to serve as an evaporator (hereinafter, also "evaporator mode operation"), refrigerant to be evaporated flows from the pipe 11c into the first chamber 213a of the first header 213 of the first heat exchanger 21. The refrigerant then flows into the first chamber 214a of the second header 214 from the first heat transfer tubes 212 connected to the first chamber 213a. In the first chamber 214a, the refrigerant turns its direction of flow before leaving the second header 214. Further, the refrigerant flows into the second chamber 213b of the first header 213 from the second header 214 through the first heat transfer tubes 212 connected to the second chamber 213b of the first header 213. Of the first heat transfer tubes 212 connected to the first chamber 214a of the second header 214, those connected to the first chamber 213a of the first header 213, and those connected to the second chamber 213b of the first header 213 allow refrigerant to flow therethrough in vertically opposite directions.

[0038] The refrigerant turns its direction of flow in the second chamber 213b of the first header 213. The refrigerant then flows out of the second chamber 213b into the second chamber 214b of the second header 214. The refrigerant then turns its direction of flow in the second chamber 214b, and flows out of the second chamber 214b of the second header 214 into the third chamber 213c of the first header 213. The refrigerant then turns its direction of flow in the third chamber 213c, and flows out of the third chamber 213c of the first header 213 into the third chamber 214c of the second header 214. Subsequently, the refrigerant flows into the first chamber 223a of the third header 223 of the second heat exchanger 22 from the third chamber 213c of the first header 213 through the connection pipe 12. The refrigerant then flows into the first chamber 224a of the fourth header 224 from the second heat transfer tubes 222 connected to the first chamber 223a of the third header 223. In the first chamber 224a of the fourth header 224, the refrigerant has its direction of flow turned. The refrigerant then flows into the second chamber 223b of the third header 223. The refrigerant turns its direction of flow in the second chamber 223b, and then flows into the second chamber 224b of the fourth header 224. Subsequently, the refrigerant exits from the pipe 11d connected to the second chamber 224b of the fourth header 224. The pipe 11d is connected such that the refrigerant is sucked into the compressor 14 after passing through the second heat exchanger 22.

[0039] During an operation in which the indoor heat exchanger 10 is made to serve as a condenser (hereinafter, also "condenser mode operation"), the direction of refrigerant flow is reverse to the direction of refrigerant flow when the indoor heat exchanger 10 is made to serve as an evaporator. That is, refrigerant enters the second chamber 224b of the fourth header 224 of the second heat exchanger 22 from the pipe 11d, and exits from the first chamber 213a of the first header 213 of the first heat exchanger 21. Refrigerant to be condensed is discharged from the compressor 14, and passes through the second heat exchanger 22 from the pipe 11d. The refrigerant is then routed through the connection pipe 12 into one of the chambers of the first header 213 of the first heat exchanger 21 or into the second header 214. Although the connection pipe 12 is depicted in FIG. 2 as being connected from the first chamber 223a of the third header 223 of the second heat exchanger 22 to the third chamber 213c of the first header 213, the connection pipe 12 may be connected to the second header 214. After being condensed by passage through the first heat exchanger 21, the refrigerant exits from the first chamber 213a of the first header 213 toward the expansion device 17.

[0040] As described above, refrigerant entering one heat exchanger from a chamber at one end of a header in the horizontal method is made to turn its direction of flow between a pair of headers connected by the first heat transfer tubes 212. The refrigerant thus travels in a meandering manner toward a side of the heat exchanger opposite from the inlet side in the horizontal direction. Then, after reaching the chamber at the opposite farthest end, the refrigerant flows out to the other heat exchanger through the connection pipe 12 or to the outside through the pipe 11c or 11d.

[0041] The sum of the number of chambers in the third header 223 of the second heat exchanger 22 and the number of chambers in the fourth header 224 of the second heat exchanger 22 is less than the sum of the number of chambers in the first header 213 of the first heat exchanger 21 and the number of chambers in the second header 214 of the first heat exchanger 21. Accordingly, the number of turns of the direction of refrigerant flow in the second heat exchanger 22 is less than the number of turns of the direction of refrigerant flow in the first heat exchanger 21.

[0042] The number of first heat transfer tubes 212 and the number of second heat transfer tubes 222 are the same. Each of the first heat transfer tubes 212 and each of the second heat transfer tubes 222 have the same channel cross-sectional area. The first header 213, the second header 214, the third header 223, and the fourth header 224 each have the same length. The first header 213 and the second header 214 are each made of a tube with the same thickness. Accordingly, the first header 213 and the second header 214 are basically the same in terms of the volume of their internal space, except for, for example, slight differences in Elements such as the partition part 4 and the connecting potion of each header with the corresponding pipe. Likewise, the third header 223 and the fourth header 224 are basically the same in terms of the volume of their internal space. Making the first header 213, the second header 214, the third header 223, and the fourth header 224 have basically the same volume of internal space allows for a relatively simple configuration. In an alternative arrangement, the third header 223 and the fourth header 224 of the second heat exchanger may each have an internal space greater than the internal space of each of the first header 213 and the second header 214, and to that end, the third header 223 and the fourth header 224 may each have a tube diameter greater than the tube diameter of each of the first header 213 and the second header 214.

[0043] The first heat transfer tubes 212 each have a length L_1 greater than a length L_2 of each of the second heat transfer tubes 222. The length L_1 of the first heat transfer tube 212 refers to a length from one end of the first heat transfer tube 212 connected to the first header 213, to the other end of the first heat transfer tube 212 connected to the second header 214. The length L_2 of the second heat transfer tube 222 refers to a length from one end of the second heat transfer tube 222 connected to the third header 223, to the other end of the second heat transfer tube 222 connected to the fourth header 224.

[0044] As for the number of first heat transfer tubes 212 connected to each of the first to third chambers 213a to 213c of the first header 213, the number of first heat transfer tubes 212 is not the same but different for each of the chambers (the first to third chambers 213a to 213c) of the first header 213. As for the number of first heat transfer tubes 212 connected to each of the first to third chambers 214a to 214c of the second header 214, the number of first heat transfer tubes 212 is not the same but different for each of the chambers (the first to third chambers 214a to 214c) of the second header 214. That is, the respective numbers of first heat transfer tubes 212 connected to the first to third chambers 213a to 213c of the first header 213 and to the first to third chambers 214a to 214c of the second header 214 are adjusted. This ensures that during condenser mode operation, after turning of the direction of refrigerant flow, the channel cross-sectional area for refrigerant does not decrease but remains the same or increases relative to the channel cross-sectional area before turning of the direction of refrigerant flow.

[0045] The mean number of second heat transfer tubes 222 connected to each of the chambers (the first chamber 223a and the chamber 223b) of the third header 223 is greater than the mean number of first heat transfer tubes 212 connected to each of the chambers (the first to third chambers 213a to 213c) of the first header 213.

[0046] In the present case, the first chamber 213a of the first header 213 is a chamber connected with the pipe 11c, the second chamber 224b of the fourth header 224 is a chamber connected with the pipe 11d, and the third chamber 214c of the second header 214, and the first chamber 223a of the third header 223 are chambers connected with the connection pipe 12. In each of the above-mentioned chambers, refrigerant does not turn back its direction of flow between the heat transfer tubes connected with the chamber. Accordingly, each of these chambers has a length shorter than the length of a chamber located adjacent to the chamber and where refrigerant turns back its direction of flow.

[0047] Reference is now made to how the indoor heat exchanger 10 operates.

<Cooling Operation>

[0048] FIG. 3 is a diagram illustrating the air-conditioning apparatus 200 including the indoor heat exchanger 10 according to Embodiment 1. In FIG. 3, the arrows represent the flow of refrigerant during cooling operation. During cooling operation of the air-conditioning apparatus 200, the indoor heat exchanger 10 serves as an evaporator, and the outdoor heat exchanger 16 serves as a condenser.

[0049] Refrigerant changes to a high-temperature, high-pressure gaseous state in the compressor 14, and flows via the four-way valve 15 into the outdoor heat exchanger 16 mounted in the outdoor unit 201. In the outdoor heat exchanger 16, the refrigerant rejects heat to the outdoor air being sent by the outdoor fan 13a, and thus changes to liquid-phase refrigerant or mainly-liquid refrigerant. The refrigerant then undergoes pressure reduction in the expansion device 17, and flows into the first heat exchanger 21 of the indoor heat exchanger 10 of the indoor unit 202. In the first heat exchanger 21, the refrigerant removes heat from the indoor air being sent by the indoor fan 13b. As the refrigerant travels from the first heat exchanger 21 of the indoor heat exchanger 10 to the second heat exchanger 22 of the indoor heat exchanger 10, the refrigerant turns from low-temperature, low-pressure two-phase refrigerant into low-pressure gas refrigerant, which then leaves the indoor heat exchanger 10, and returns to the compressor 14 again via the four-way valve 15.

[0050] FIG. 4 illustrates the relationship between the evaporator performance of the indoor heat exchanger 10, and heat-transfer-tube length ratio according to Embodiment 1. In FIG. 4, the vertical axis represents evaporator performance, and the horizontal axis represents heat-transfer-tube length ratio.

[0051] The heat-transfer-tube length ratio refers to the ratio of L_1, which is the length of the first heat transfer tube 212, to $L_1 + L_2$, which is the sum of the length of the first heat transfer tube 212 and the length of the second heat transfer tube 222.

[0052] As illustrated in FIG. 4, as the heat-transfer-tube length ratio increases, pressure loss becomes less likely to decrease, which leads to enhanced evaporator performance. As the heat-transfer-tube length ratio decreases, pressure loss decreases, which leads to degradation of evaporator performance.

[0053] When the indoor heat exchanger 10 serves as an evaporator, the refrigerant that has undergone pressure reduction in the expansion device 17 removes heat from indoor air in the first heat transfer tubes 212 of the first heat exchanger 21, and increases in quality. The refrigerant with higher quality then flows through the second heat transfer tubes 222 of the second heat exchanger 22.

[0054] At this time, the volume flow rate of refrigerant through the second heat exchanger 22 is greater than the volume flow rate of refrigerant through the first heat exchanger 21. Therefore, increasing the length L_2 of the second heat transfer tube 222 relative to the length L_1 of the first heat transfer tube 212, that is, decreasing the heat-transfer-tube length ratio causes pressure loss in the second heat transfer tube 222 to increase. This results in decreased saturation temperature in the indoor heat exchanger 10, and consequently degradation of evaporator performance.

[0055] Decreasing the length L_2 of the second heat transfer tube 222 relative to the length L_1 of the first heat transfer tube 212, that is, increasing the heat-transfer-tube length ratio results in reduced length of the path through which refrigerant with higher quality passes. This leads to reduced pressure loss in the second heat transfer tube 222, increased saturation temperature in the indoor heat exchanger 10, and consequently enhanced evaporator performance.

cheating Operation>

[0056] FIG. 5 is a diagram illustrating the air-conditioning apparatus 200 including the indoor heat exchanger 10 according to Embodiment 1. In FIG. 5, the arrows represent the flow of refrigerant during heating operation.

[0057] During heating operation of the air-conditioning apparatus 200, the indoor heat exchanger 10 serves as a condenser, and the outdoor heat exchanger 16 serves as an evaporator.

[0058] Refrigerant changes to a high-temperature, high-pressure gaseous state in the compressor 14, and flows via the four-way valve 15 into the indoor heat exchanger 10 mounted in the indoor unit 202. In the first heat exchanger 21 and the second heat exchanger 22 of the indoor heat exchanger 10, the refrigerant rejects heat to the indoor air being sent by the indoor fan 13b, and thus changes to liquid-phase refrigerant or mainly-liquid refrigerant, which then leaves the indoor heat exchanger 10. Subsequently, the refrigerant undergoes pressure reduction in the expansion device 17, and in the outdoor heat exchanger 16 of the outdoor unit 201, the refrigerant removes heat from the outside air being sent by the outdoor fan 13a. The refrigerant thus changes from a low-temperature, low-pressure two-phase state to a low-pressure gaseous state. The resulting refrigerant then leaves the outdoor heat exchanger 16, and returns to the compressor 14 again via the four-way valve 15.

[0059] FIG. 6 illustrates the relationship between the amount of refrigerant within the indoor heat exchanger 10, and heat-transfer-tube length ratio according to Embodiment 1. In FIG. 6, the vertical axis represents the amount of refrigerant, and the horizontal axis represents heat-transfer-tube length ratio.

[0060] As illustrated in FIG. 6, a low heat-transfer-tube length ratio results in increased refrigerant density, and consequently increased amount of refrigerant within the indoor heat exchanger 10. A high heat-transfer-tube length ratio results in decreased refrigerant density, and consequently decreased amount of refrigerant within the indoor heat exchanger 10.

[0061] When the indoor heat exchanger 10 serves as a condenser, refrigerant with high quality enters the indoor heat exchanger 10 from the second heat exchanger 22, and travels through the second heat exchanger 22 and the first heat exchanger 21 while rejecting heat to indoor air. This causes the refrigerant to decrease in quality, and the refrigerant with lower quality exits from the first heat exchanger 21.

[0062] At this time, low refrigerant quality in the third header 223 and the fourth header 224 of the second heat exchanger 22 results in increased mean refrigerant density in the third header 223 and the fourth header 224. This leads to an increase in the amount of refrigerant in the third header 223 and the fourth header 224, and consequently an increase in the amount of refrigerant within the indoor heat exchanger 10.

[0063] Increasing the length L_1 of the first heat transfer tube 212 relative to the length L_2 of the second heat transfer tube 222 helps to facilitate heat transfer in the first heat exchanger 21, which results in increased quality in the third header 223 and the fourth header 224 of the second heat exchanger 22. This leads to decreased mean refrigerant density and consequently reduced amount of refrigerant in the indoor heat exchanger 10.

[0064] In this way, the configuration described above leads to an increase in the saturation temperature in the indoor heat exchanger 10 for an operation in which the indoor heat exchanger 10 serves as an evaporator, and to a decrease in the mean refrigerant density in the indoor heat exchanger 10 for an operation in which the indoor heat exchanger 10 serves as a condenser.

[0065] This makes it possible to achieve both enhanced performance and energy saving of the air-conditioning apparatus 200.

[0066] The number of partition parts 4 that divide the internal space of each of the first header 213, the second header 214, the third header 223, and the fourth header 224, and the number of chambers into which the internal space is to be divided may be changed as appropriate. In an alternative configuration, each of the third header 223 and the fourth header 224 may include no partition part 4, and may thus include only a single chamber.

[0067] It is to be noted, however, that the sum of the number of chambers in the third header 223 of the second heat exchanger 22, and the number of chambers in the fourth header 224 of the second heat exchanger 22 is less than the sum of the number of chambers in the first header 213 of the first heat exchanger 21, and the number of chambers in the second header 214 of the first heat exchanger 21. Alternatively, the number of chambers in the first header 213 or the second header 214 of the first heat exchanger 21, which is a header connected with the connection pipe 12, is greater than the number of chambers in the third header 223 of the second heat exchanger 22, which is a header connected with the connection pipe 12. As a result, the number of turns of the direction of refrigerant flow in the second heat exchanger 22 is less than the number of turns of the direction of refrigerant flow in the first heat exchanger 21. This reduces pressure loss caused by collision or friction between refrigerant and the interior wall surface of each of the third header 223 and the fourth header 224.

[0068] During evaporator mode operation, the following relationship holds: the number of first heat transfer tubes 212 connected to a chamber of the first heat exchanger 21 that is connected to the pipe 11c and into which liquid-containing refrigerant enters < the number of first heat transfer tubes 212 connected to a chamber of the first heat exchanger 21 from which refrigerant flows out into the connection pipe 12 ≤ the number of second heat transfer tubes 222 connected to a chamber of the second heat exchanger 22 into which refrigerant enters from the connection pipe 12 ≤ the number of second heat transfer tubes 222 connected to a chamber of the second heat exchanger 22 that is connected to the pipe 11d and from which gasified refrigerant exits.

[0069] The protrusion of the second heat transfer tube 222 into the third header 223 and the fourth header 224 helps to ensure that even if there is an expansion or contraction of flow, pressure loss caused by the resistance to refrigerant flow can be reduced.

[0070] Unlike the first heat exchanger 21, the second heat exchanger 22 may be designed such that the channel cross-sectional area does not vary across the entire refrigerant path. The first chamber 223a of the third header 223 and the second chamber 224b of the fourth header 224, which are chambers from or into which refrigerant exits to or enters from the outside and where refrigerant does not turn back its direction of flow, may be made to have the same size. The second chamber 223b of the third header 223 and the first chamber 224a of the fourth header 224, which are chambers where refrigerant turns back its direction of flow, may be made to have the same size.

[0071] Desirably, the number of second heat transfer tubes 222 connected to the first chamber 223a of the third header 223 and the number of second heat transfer tubes 222 connected to the second chamber 224b of the fourth header 224 are the same, and the number of second heat transfer tubes 222 connected to the second chamber 223b of the third header 223 and the number of second heat transfer tubes 222 connected to the first chamber 224a of the fourth header 224 are the same. That is, the number of second heat transfer tubes 222 through which refrigerant flows from one of the chambers in the third header 223 and the fourth header 224, toward a chamber in the fourth header 224 and the third header 223 opposite from the one chamber is the same between the third and the fourth headers 223 and 224. This helps to ensure that for the second heat exchanger 22 with a relatively small length of its heat transfer tubes, a large channel cross-sectional area can be maintained across the entire length of the heat transfer tubes.

[0072] In some cases, dividing the number of second heat transfer tubes 222 connected to the third header

223 by the number of chambers in the third header 223 may result in a non-integer quotient. In such a case, it may be desirable to adjust the respective numbers of second heat transfer tubes 222 connected to individual chambers in the third header 223 to integers by adding or subtracting a number less than 1 to or from the quotient, and to make the difference between the numbers of second heat transfer tubes 222 less than or equal to 1. This results in roughly the same, although not exactly the same, number of second heat transfer tubes 222 in each chamber. As a result, the effect mentioned above can be obtained.

[0073] For example, if the number of second heat transfer tubes 222 connected to the third header 223 is 21, and the number of chambers in the third header 223 is 2, then the respective numbers of second heat transfer tubes 222 connected to the two chambers are 10 and 11. Although the above-mentioned adjustment may in some cases result in an about 10 % change in the size of each chamber in the third header 223, even in such cases, it is regarded according to the present invention that such a plurality of chambers are equal in size, and these chambers are connected with the same number of second heat transfer tubes 222.

[0074] The quality of refrigerant flowing through the third header 223 and the fourth header 224 is higher than the quality of refrigerant flowing through the first header 213. Accordingly, maintaining a large channel cross-sectional area across the entire path of refrigerant flow through the second heat exchanger 22 makes it possible to reduce pressure loss in the second heat exchanger 22 when the indoor heat exchanger 10 is operating as an evaporator.

[0075] The first header 213 is divided into individual chambers (the first to third chambers 213a to 213c) such that these chambers have a mean size smaller than the mean size of the chambers (the first and second chambers 223a and 223b) in the third header 223. That is, during condenser mode operation of the indoor heat exchanger 10, the individual divided chambers (the first to third chambers 213a to 213c) in the first heat exchanger 21 located downstream in the flow of refrigerant have a mean size smaller than the mean size of the individual divided chambers (the first and second chambers 223a and 223b) in the second heat exchanger 22. As a result, in the indoor heat exchanger 10, formation of regions where refrigerant exists in a subcooled state with high refrigerant density can be reduced, and consequently, the amount of refrigerant can be reduced.

[0076] The foregoing description is directed to an example in which the indoor heat exchanger 10 includes the first heat exchanger 21 and the second heat exchanger 22. In an alternative configuration, instead of the indoor heat exchanger 10, the outdoor heat exchanger 16 may include the first heat exchanger 21 and the second heat exchanger 22.

[0077] In another alternative configuration, the indoor heat exchanger 10 may include the first heat exchanger 21 and the second heat exchanger 22, and the outdoor heat exchanger 16 may likewise include the first heat exchanger 21 and the second heat exchanger 22.

[0078] The pipe 11c, which is a pipe through which two-phase refrigerant flows when the indoor heat exchanger 10 operates as a condenser, is longer than the pipe 11b, which is a pipe through which two-phase refrigerant flows when the outdoor heat exchanger 16 operates as a condenser. Accordingly, from the viewpoint of reducing the amount of refrigerant during condenser mode operation, employing a configuration in which the indoor heat exchanger 10 is made up of the first heat exchanger 21 and the second heat exchanger 22 allows for greater reduction in the amount of refrigerant.

[0079] In the air-conditioning apparatus 200 according to Embodiment 1, the length L_1 of the first heat transfer tube 212 of the first heat exchanger 21 constituting the indoor heat exchanger 10 is greater than the length L_2 of the second heat transfer tube 222 of the second heat exchanger 22. Accordingly, when the indoor heat exchanger 10 is made to serve as an evaporator, refrigerant with high quality flows through the second heat transfer tube 222 of the second heat exchanger 22, which has a length less than the length L_1 of the first heat transfer tube 212 of the first heat exchanger 21. This results in reduced pressure loss, and enhanced performance of the indoor heat exchanger 10. When the indoor heat exchanger 10 is made to serve as a condenser, heat exchange in the first heat exchanger 21 is facilitated, which in turn facilitates passage of refrigerant with high quality. This makes it possible to reduce mean refrigerant density in the first header 213, the second header 214, the third header 223, and the fourth header 224, and consequently achieve refrigerant saving.

[0080] The refrigerant pipe through which refrigerant with high quality flows when the indoor heat exchanger 10 serves as a condenser is longer than the refrigerant pipe through which refrigerant with high quality flows when the outdoor heat exchanger 16 serves as a condenser. Accordingly, employing a configuration in which the indoor heat exchanger 10 includes the first heat exchanger 21 and the second heat exchanger 22 allows for increased energy saving.

[0081] As described above, the number of chambers (the first to third chambers 213a to 213c) in the first header 213 is greater than the number of chambers (the first chamber 223a and the second chamber 223b) in the third header 223. This leads to reduced pressure loss within the third header 223 when the indoor heat exchanger 10 serves as an evaporator. This makes it possible to enhance the performance of the indoor heat exchanger 10.

[0082] Of the chambers 213a to 213c in the first header 213, the first chamber 213a, which is located downstream in the direction of refrigerant flow when the indoor heat exchanger 10 is serving as a condenser, is smaller than the second chamber 213b and the third chamber 213c, which are located upstream in the direction of refrigerant flow. This reduces the risk of refrigerant in a low-quality, subcooled state accumulating in the first header 213.

[0083] The third header 223 is divided into the first chamber 223a and the second chamber 223b that are of the same size. The division into equal-sized chambers helps to ensure that when the indoor heat exchanger 10 serves as an evaporator, a channel in which refrigerant with high quality flows can be increased in cross-sectional area, which allows for reduced pressure loss and enhanced performance.

[0084] If a refrigerant with a low gas density relative to an R32 refrigerant or an R410A refrigerant is used as the refrigerant, the refrigerant flow velocity per unit capacity increases. Accordingly, the performance improvement due to reduced pressure loss becomes more pronounced. Examples of such a refrigerant include an olefin-based refrigerant, propane, and dimethyl ether (DME) that contain double-bonds in their molecules, such as HFO1234yf and HFP1234ze(E).

[0085] The first heat exchanger 21 and the second heat exchanger 22 may be integral with each other as long as such an integral construction allows the constraints on the respective lengths of the first and second heat transfer tubes 212 and 222 to be met.

<First Modification>

[0086] FIG. 7 is a diagram of the indoor heat exchanger 10 according to a first modification of Embodiment 1.

[0087] As illustrated in FIG. 7, the configuration of the indoor heat exchanger 10 according to the first modification differs from that illustrated in FIG. 2 in the location where each of the pipes 11c and 11d is connected. In the first heat exchanger 21 illustrated in FIG. 2, the pipe 11c is connected to the first header 213, and the connection pipe 12 is connected to the second header 214. That is, the pipe 11c and the connection pipe 12 are connected to different headers.

[0088] In the second heat exchanger 22 illustrated in FIG. 2, the pipe 11d is connected to the fourth header 224, and the connection pipe 12 is connected to the third header 223. That is, the pipe 11d and the connection pipe 12 are connected to different headers. By contrast, according to the first modification illustrated in FIG. 7, in the first heat exchanger 21, the pipe 11c and the connection pipe 12 are connected to the same header, which is the first header 213. According to the first modification, in the second heat exchanger 22, the pipe 11d and the connection pipe 12 are connected to the same header, which is the third header 223. In FIG. 7, the internal space of the third header 223 is divided into a plurality of chambers (the first chamber 223a and the second chamber 223b) that are equal in size.

[0089] In the indoor heat exchanger 10, the second header 214 and the fourth header 224 are the two headers that are located farthest from each other, and the first header 213 and the third header 223 are the two headers that are located closest to each other. As with the configuration in FIG. 2, according to the first modification, the connection pipe 12 likewise connects two chambers located at respective one ends of the first header 213 and the third header 223, which are two closely located headers. The above-mentioned configuration, that is, connecting the respective one ends in the horizontal direction of two closely located headers in this way is effective for shortening the connection pipe 12.

[0090] The pipes 11c and 11d through which refrigerant is allowed to enter or exit are respectively connected to the other ends in the horizontal direction of the first header 213 and the third header 223, which are two closely located headers. The second header 214 and the fourth header 224 are connected with no pipe. This configuration is advantageous for making pipe routing simpler and downsizing the indoor heat exchanger 10. This configuration is also effective for reducing the amount of refrigerant.

[0091] Since the configuration in FIG. 7 differs from that in FIG. 2 in how the pipes 11c and 11d and the connection pipe 12 are connected, the number of chambers and the number of partition parts 4 in some of the headers in FIG. 7 also differ from those in FIG. 2. The first header 213 connected with the pipe 11c and the connection pipe 12 is divided by three partition parts 4 into four chambers 213a to 213d. The first header includes a number of partition parts 4 and a number of chambers that are greater than those in the second header 214 connected with no pipe. Likewise, the third header 223 connected with the pipe 11d and the connection pipe 12 is divided by two partition parts 4 into two chambers 213a and 213b. The fourth header 224 includes no partition part 4, and is made up of a single chamber. The third header includes a number of partition parts 4 and a number of chambers that are greater than those in the fourth header 224 connected with no pipe.

[0092] As with the configuration in FIG. 2, the first heat transfer tube 212 of the first heat exchanger 21 is longer than the second heat transfer tube 222 of the second heat exchanger 22. Further, as with the configuration in FIG. 2, the number of partition parts 4 in the first header 213 is greater than the number of partition parts 4 in the third header 223, the number of chambers in the first header 213 is greater than the number of chambers in the third header 223, and the mean size of the chambers in the first header 213 is less than the mean size of the chambers in the third header 223. As with the configuration in FIG. 2, the configuration according to the first modification allows for both refrigerant saving and reduced pressure loss, and also downsizing of the heat exchanger.

<Second Modification>

[0093] FIG. 8 is a diagram of the indoor heat exchanger 10 according to a second modification of Embodiment 1. As illustrated in FIG. 8, the indoor heat exchanger 10 according to the second modification includes the first heat exchanger 21, the second heat exchanger 22, and a third heat exchanger 23.

[0094] The first header 213 of the first heat exchanger 21 is divided by a plurality of partition parts 4 into a plurality of chambers 213a to 213c. The second header 214 is divided by a plurality of partition parts 4 into a plurality of chambers 214a to 214c.

[0095] The third header 223 of the second heat exchanger 22 is divided into a first chamber 223a and a second chamber 223b.

[0096] The third heat exchanger 23 is a serpentine heat exchanger in which a single third heat transfer tube 6 makes a turn a plurality of times.

[0097] The third heat transfer tube 6 of the third heat exchanger 23 is connected at one end 8 to the pipe 11c, and connected at the other end 7 to the first chamber 213a of the first header 213.

[0098] A length L_3 from the location of a turn in the third heat transfer tube 6 to the location of the next turn is less than the length L_1 of the first heat transfer tube 212 of the first heat exchanger 21. The total tube path length of the third heat transfer tube 6 is greater than the length L_1 of the first heat transfer tube 212.

[0099] In the indoor heat exchanger 10 according to the second modification, when the indoor heat exchanger 10 operates as an evaporator, refrigerant enters the one end 8 of the third heat transfer tube 6 from the pipe 11c, and flows toward the other end 7 of the third heat transfer tube 6. The refrigerant then flows from the other end 7 into the first chamber 213a of the first header 213.

[0100] The refrigerant flows from the first chamber 213a of the first header 213 through the following chambers before entering the third chamber 213c of the first header 213: the first chamber 214a of the second header 214; the second chamber 213b of the first header 213; and then the second chamber 214b of the second header 214.

[0101] Subsequently, the refrigerant is routed through the third chamber 214c of the second header 214 from the third chamber 213c of the first header 213, and passes through the connection pipe 12 into the first chamber 223a of the third header 223. After then passing through the fourth header 224, the refrigerant reaches the second chamber 223b of the third header 223, and exits from the pipe 11d.

[0102] At this time, although the length L_3 from the location of a turn in the third heat transfer tube 6 to the location of the next turn is less than the length L_1 of the first heat transfer tube 212, the total tube path length of the third heat transfer tube 6 is greater than the length L_1 of the first heat transfer tube 212. The second modification can be may be considered as a modification of the configurations illustrated in Figs. 2 and 7 such that the third heat exchanger 23 is disposed between the pipe 11c, and the first chamber 213a of the first header 213 to which the pipe 11c is connected. As compared with the first heat transfer tubes 212 connected to the first chamber 213a of the first header 213, the third heat exchanger 23 has a long heat transfer tube, or a small number of heat transfer tubes, and accordingly, has a small channel cross-sectional area. This helps to reduce the density of refrigerant entering the second header 214, and consequently reduce the mean amount of refrigerant for the first header 213, the second header 214, the third header 223, and the fourth header 224 as a whole.

Embodiment 2

[0103] FIG. 9 is a diagram illustrating the indoor unit 202 according to Embodiment 2. The indoor unit 202 according to Embodiment 2 is an example of the indoor unit 202 of the air-conditioning apparatus 200 according to Embodiment 1.

[0104] As illustrated in FIG. 9, in the indoor unit 202 according to Embodiment 2, the second header 214 of the first heat exchanger 21 is located at a height that is lower in a vertical direction 31 than the height at which the fourth header 224 of the second heat exchanger 22 is located. The first header 213 of the first heat exchanger 21, and the third header 223 of the second heat exchanger 22 are at the same height. The first heat transfer tube 212 of the first heat exchanger 21, and the second heat transfer tube 222 of the second heat exchanger 22 are both inclined with respect to the vertical direction. The first header 213 and the third header 223, which are located at the respective upper ends of the first heat transfer tube 212 and the second heat transfer tube 222, are positioned close to each other in the horizontal direction. The second header 214 and the fourth header 224, which are located at the respective lower ends of the first heat transfer tube 212 and the second heat transfer tube 222, are positioned apart from each other in the horizontal direction.

[0105] That is, in the indoor unit 202 according to Embodiment 2, a lowermost part 41 of the first heat exchanger 21 is positioned lower in the vertical direction 31 than a lowermost part 42 of the second heat exchanger 22.

[0106] FIG. 10 is a diagram illustrating the flow of refrigerant through the connection pipe 12 of the indoor heat exchanger 10 illustrated in FIG. 9. FIG. 10 illustrates the flow of refrigerant during condenser mode operation of the indoor heat exchanger 10. The refrigerant in this case is a mixture of a liquid-phase refrigerant 61 and a gas-phase refrigerant 62, each of which flows within the connection pipe 12. FIG. 10 illustrates a configuration in which the connection pipe 12 having a U-shape connects the top face of the first header 213 and the top face of the third header 223. In an alternative configuration, the connection pipe 12 may connect the respective ends of the first header 213 and the third header 223 in the horizontal direction, that is, the connection pipe 12 may extend in a U-shape in a direction toward or away from the plane of FIG. 10.

[0107] As illustrated in FIG. 10, during condenser mode operation of the indoor heat exchanger 10, refrigerant flows from the second heat exchanger 22 to the first heat exchanger 21 in a refrigerant flow direction 30 via the connection pipe 12. Refrigerant flowing in the first heat exchanger 21 has a lower quality than refrigerant flowing in the second heat exchanger 22. Refrigerant flowing within the connection pipe 12 has a quality that is intermediate between the quality of refrigerant flowing in the first heat exchanger 21 and the quality of refrigerant flowing in the second heat exchanger 22.

[0108] As the liquid-phase refrigerant 61 moves in the connection pipe 12, the liquid-phase refrigerant 61 experiences an inertial force 52, which acts in the direction of refrigerant flow, and a gravitational force 51. Within each header, the channel cross-sectional area is larger than the channel cross-sectional area in each heat transfer tube, and thus the velocity of refrigerant decreases. As a result, the inertial force 52 decreases, and the influence of the gravitational force 51 increases.

[0109] At higher refrigerant flow rates, the inertial force 52 acting on the liquid-phase refrigerant 61 is greater than the gravitational force 51 acting on the liquid-phase refrigerant 61. This allows the liquid-phase refrigerant 61 in the connection pipe 12 to flow from the second heat exchanger 22 toward the first heat exchanger 21, that is, in the refrigerant flow direction 30.

[0110] During low-capacity operation, the refrigerant flow rate decreases. As a result, the inertial force 52 decreases, and the influence of the gravitational force 51 increases.

[0111] At this time, if the first heat transfer tube 212 of the first heat exchanger 21 is shorter than the second heat transfer tube 222 of the second heat exchanger 22, the relative influence of the gravitational force 51 that acts in the direction of the second heat exchanger 22 increases. As a consequence, the influence of the gravitational force 51 acting in the direction of the second heat exchanger 22 increases relative to the inertial force 52 acting on the liquid-phase refrigerant 61 in the connection pipe 12. This makes it harder for the liquid-phase refrigerant 61 to flow in the refrigerant flow direction 30. As a result, the liquid-phase refrigerant 61 tends to stay particularly in the header where the inertial force 52 is relatively small, and in the connection pipe 12. This leads to increased refrigerant density in the second heat exchanger 22, and consequently increased amount of refrigerant.

[0112] According to Embodiment 2, the first heat transfer tube 212 of the first heat exchanger 21 is longer than the second heat transfer tube 222 of the second heat exchanger 22. Consequently, the influence of the gravitational force 51 acting in the direction of the first heat exchanger 21 is greater than the influence of the gravitational force 51 acting in the direction of the second heat exchanger 22. As a result, even when the inertial force 52 acting on the liquid-phase refrigerant 61 decreases during low-capacity operation, refrigerant can be moved in the refrigerant flow direction 30. This helps to mitigate an increase in refrigerant density during low-capacity operation, and consequently achieve refrigerant saving.

[0113] The air-conditioning apparatus 200 according to Embodiment 2 described above is designed such that in the indoor heat exchanger 10, the lowermost part 41 of the first heat exchanger 21 is positioned lower in the vertical direction 31 than the lowermost part 42 of the second heat exchanger 22. Such positioning helps to, during serving of the indoor heat exchanger 10 as a condenser, mitigate an increase in refrigerant density in the second heat exchanger 22, which occurs due to the increased difficulty with which the liquid-phase refrigerant 61 to be directed toward the first heat exchanger 21 flows in the refrigerant flow direction 30. As a result, refrigerant saving can be achieved.

[0114] As described above, the second heat transfer tube 222 is shorter than the first heat transfer tube 212. Consequently, the amount of heat exchange in the second heat exchanger 22 is small relative to when the second heat transfer tube 222 has the same length as the first heat transfer tube 212. This results in relatively high quality in the second heat exchanger 22. This ensures that even when the liquid-phase refrigerant 61 stays in the header and the connection pipe 12, the amount of such refrigerant is small. By contrast, the quality in the first heat exchanger 21 decreases, which causes part of the first header 213 and the second header 214 to have areas of slightly decreased quality. However, in making the indoor heat exchanger 10 serve as a condenser, it is common to bring refrigerant into a subcooled state in the first place, and thus the amount of refrigerant does not change at locations where only the liquid-phase refrigerant 61 flows. As a result, an overall decrease in the amount of the liquid-phase refrigerant 61 is achieved for the heat exchanger according to Embodiment 2.

Embodiment 3

[0115] In Embodiment 3, reference will be made to the relationship between the indoor heat exchanger 10 and the indoor fan 13b in the indoor unit 202 of the air-conditioning apparatus 200 according to Embodiment 1. In Embodiment 3, a fan with a rotation axis extending in the horizontal direction, such as a cross-flow fan, is employed as the indoor fan 13b. The air-conditioning apparatus 200 and the indoor heat exchanger 10 are similar in configuration to those in Embodiment 1, and thus will not be described in further detail. Elements in Embodiment 3 that are similar or corresponding to those in Embodiment 1 will be designated by the same reference signs.

[0116] FIG. 11 is a perspective view of the indoor unit 202 according to Embodiment 3. As illustrated in FIG. 11, the indoor unit 202 incorporates, as the indoor fan 13b, a cross-flow fan that operates at low pressure and high air flow rate, such as a cross-flow fan. The indoor fan 13b generates an air flow in the circumferential direction of a rotation axis 18.

[0117] In the indoor heat exchanger 10, the first heat transfer tube 212 and second heat transfer tube 222 are disposed in the circumferential direction of the rotation axis 18 and tangentially to a circle centered on the rotation axis 18 of the indoor fan 13b. Refrigerant flows in the circumferential direction of the rotation axis 18.

[0118] The first heat exchanger 21 is disposed such that the first header 213 and the second header 214 extend in a direction parallel to the direction of the rotation axis 18 of the indoor fan 13b. The second heat exchanger 22 is disposed such that the third header 223 and the fourth header 224 extend in a direction parallel to the direction of the rotation axis 18 of the indoor fan 13b.

[0119] FIG. 12 is a diagram of an A-A cross-section of the indoor unit 202 illustrated in FIG. 11. As illustrated in FIG. 12, the first heat exchanger 21 and the second heat exchanger 22 are disposed at different locations in the circumferential direction of the rotation axis 18 of the indoor fan 13b. That is, the first header 213, the second header 214, the third header 223, and the fourth header 224 do not overlap each other in the radial direction of the rotation axis 18. The first heat exchanger 21 and the second heat exchanger 22 are disposed side-by-side with respect to the flow of air entering the indoor fan 13b.

[0120] Disposing the first heat exchanger 21 and the second heat exchanger 22 side-by-side with respect to the air flow as described above causes the static pressure of the air flow to decrease, which results in increased air flow rate. This improves heat transfer performance, and helps to reduce formation of subcooled refrigerant regions during condenser mode operation of the indoor heat exchanger 10. This in turn helps to reduce refrigerant density, and consequently achieve refrigerant saving.

[0121] FIG. 13 is a diagram of an A-A cross-section of the indoor unit 202 according to a comparative example. As illustrated in FIG. 13, in the indoor unit 202 according to the comparative example, the first heat exchanger 21 and the second heat exchanger 22 are disposed at the same location in the circumferential direction with respect to the rotation axis 18 of the indoor fan 13b. That is, the first heat exchanger 21 and the second heat exchanger 22 are disposed in series with respect to the air flow produced by the indoor fan 13b.

[0122] If the first heat exchanger 21 and the second heat exchanger 22 are disposed as in the indoor unit 202 according to the comparative example, the flow of air through the indoor heat exchanger 10 tends to be obstructed. This is because the first header 213, the second header 214, the third header 223, and the fourth header 224 are located at different heights due to the difference in length between the first heat transfer tube 212 of the first heat exchanger 21 and the second heat transfer tube 222 of the second heat exchanger 22.

[0123] Disposing the first heat exchanger 21 and the second heat exchanger 22 side-by-side with respect to the air flow as in the indoor unit 202 according to Embodiment 3 results in decreased static pressure of the air flow and enhanced air flow rate, and consequently improved heat transfer performance. This helps to reduce formation of subcooled refrigerant regions during condenser mode operation of the indoor heat exchanger 10. Refrigerant density can be thus reduced for refrigerant saving.

[0124] FIG. 14 is a diagram for explaining the relationship between the indoor fan 13b of the indoor unit 202, and air velocity according to Embodiment 3. In FIG. 14, the position of a corner C at one end of the second header 214 is defined as 0 %, and the position of a corner D at the other end of the second header 214, which is a position reached through movement from the corner C in a rotation axis direction 33, is defined as 100 %. In FIG. 14, the position of a corner E at one end of the fourth header 224, which is a position reached through movement from the corner C in a circumferential direction 34 of the rotation axis 18 along the first heat transfer tube 212 and second heat transfer tube 222, is defined as 100 %.

[0125] FIG. 15 illustrates the relationship between position in the rotation axis direction 33 of the indoor fan 13b illustrated in FIG. 14, and air velocity, and the relationship between position in the circumferential direction 34 of the rotation axis 18 of the indoor fan 13b, and air velocity. In FIG. 15, the solid line represents the relationship between position in the rotation axis direction 33 of the indoor fan 13b, and air velocity, and the broken line represents the relationship between position in the circumferential direction 34 of the rotation axis 18 of the indoor fan 13b, and air velocity.

[0126] As illustrated in Figs. 14 and 15, if the first heat exchanger 21 and the second heat exchanger 22 are located upstream of the indoor fan 13b, low-temperature air that has passed through the first heat exchanger 21, and high-temperature air that has passed through the second heat exchanger 22 are mixed together by the indoor fan 13b.

[0127] The above configuration leads to a reduced refrigerant saturation temperature required for blowing air at a temperature higher than or equal to a predetermined temperature during condenser mode operation. This results in enhanced performance per unit temperature of air provided to the user.

[0128] If a refrigerant flow is provided in a direction parallel to the rotation axis 18 of the indoor fan 13b, this results in large variability in air velocity in the circumferential direction of the rotation axis 18 of the indoor fan 13b. The resulting large variations in heat exchange capacity among heat transfer tubes leads to formation of regions with increased degree of refrigerant subcooling during condenser mode operation. This results in decreased refrigerant saving effect.

[0129] By contrast, according to Embodiment 3, the first heat transfer tubes 212 and second heat transfer tubes 222 are disposed in the circumferential direction of the rotation axis 18 of the indoor fan 13b and tangentially to a circle centered on the rotation axis 18. Consequently, refrigerant flows in the circumferential direction of the rotation axis 18 of the indoor fan 13b, which is a direction in which the variability in air velocity in the rotation axis direction 33 is relatively small. This configuration leads to reduced variations in heat exchange capacity among the first heat transfer tubes 212 and the second heat transfer tubes 222. During condenser mode operation, the above-mentioned configuration makes it possible to reduce the difference in the degree of subcooling and achieve refrigerant saving. During condenser mode operation and during evaporator mode operation, the above-mentioned configuration makes it possible to reduce non-uniformity of thermal load and enhance performance. It is therefore possible to achieve both refrigerant saving and enhanced performance.

[0130] The air-conditioning apparatus 200 according to Embodiment 3 described above employs a cross-flow fan as the indoor fan 13b, and includes the first heat exchanger 21 and the second heat exchanger 22 that are disposed side-by-side in the circumferential direction with respect to the rotation axis 18 of the indoor fan 13b. This results in decreased static pressure of the air flow and enhanced air flow rate, which leads to improved heat exchange in the first heat exchanger 21 and the second heat exchanger 22 and reduced formation of subcooled regions during condenser mode operation.

[0131] FIG. 16 is a diagram illustrating the configuration of refrigerant channels in the indoor heat exchanger 10 according to Embodiment 3. FIG. 17 is a characteristic diagram illustrating improvements in refrigerant saving and heat exchange performance with respect to the configuration of refrigerant channels. As illustrated in FIG. 16, in the indoor heat exchanger 10, the first heat transfer tubes 212 connecting the first header 213 and the second header 214, and the second heat transfer tubes 222 connecting the third header 223 and the fourth header 224 allow refrigerant to flow in a meandering manner between two opposite headers as represented by hollow arrows. In the example illustrated in FIG. 16, refrigerant from the pipe 11c connected to the first heat exchanger 21 passes through the following parts in the order stated below before entering the second heat exchanger 22 from the connection pipe 12: the first chamber 213a of the first header 213; two first heat transfer tubes 212; the first chamber 214a of the second header 214; three first heat transfer tubes 212; the second chamber 213b of the first header 213; three first heat transfer tubes 212; the second chamber 214b of the second header 214; three first heat transfer tubes 212; the third chamber 213c of the first header 213; five first heat transfer tubes 212; the third chamber 214c of the second header 214; five first heat transfer tubes 212; and then the fourth chamber 213d of the first header 213. The total number of first heat transfer tubes 212 connecting the first header 213 and the second header 214 is 21.

[0132] The first heat transfer tubes 212 connecting the respective chambers of opposite headers are divided into six groups of first heat transfer tubes 212 through which refrigerant flows while changing its direction as represented by the hollow arrows. As described above, the first heat transfer tubes 212 are divided into groups such that, of the first heat transfer tubes 212, a first heat transfer tube 212 and a first heat transfer tube 212 belong to the same group if a chamber of the first header 213 to which these first heat transfer tubes 212 are connected at one end, and a chamber of the second header 214 to which these first heat transfer tubes 212 are connected at the other end are the same between these first heat transfer tubes 212, and belong to different groups if these chambers are different between these first heat transfer tubes 212. When the flow of refrigerant through the heat transfer tubes changes direction and turns back within a chamber of a header as described above, this is referred to as "turn", and the number of turns made within a single heat exchanger is referred to as the number of turns.

[0133] In FIG. 16, the first heat transfer tubes 212 are divided into groups located in between the pipe 11c and the connection pipe 12, and the respective numbers of first heat transfer tubes 212 included in these groups are denoted by $n_{1,1}$, $n_{1,2}$, $n_{1,3}$, $n_{1,4}$, $n_{1,5}$, and $n_{1,6}$. Within each group of first heat transfer tubes 212, refrigerant flows in the same direction without making a turn. The direction of refrigerant flow is opposite between adjacent groups of first heat transfer tubes 212. The number of groups where the flow makes a turn and reverses direction is equal to the number of turns plus 1.

[0134] Now, the number of first heat transfer tubes 212 in each individual group is squared and summed for all groups to obtain a sum total, and the sum total is divided by the total number of first heat transfer tubes 212 in all groups to obtain a mean number of branches N1 in the first heat exchanger 21. This can be given by the following mathematical expression: $N1= \Sigma(n_{1,k} \times n_{1,k})/\Sigma_{n1,k}$. In the example illustrated in FIG. 16, as for the first heat exchanger 21 with a total of 21 first heat transfer tubes 212, the number of turns is 5, the number of groups is 6, the sum total of the squares of the numbers of first heat transfer tubes 212 in individual groups is 81, and the mean number of branches N1 is approximately 3.9.

[0135] Likewise, in the second heat exchanger 22, refrigerant from the connection pipe 12 passes through the following parts in the order stated below before exiting from the pipe 11d: the first chamber 223a of the third header 223; 10 second heat transfer tubes 222; the first chamber 224a of the fourth header 224; 11 second heat transfer tubes 222; and then the second chamber 223b of the third header 223. As with the first heat exchanger 21, the total number of second heat transfer tubes 222 connecting the first header 213 and the second header 214 is 21. The second heat transfer tube 222 connecting the respective chambers of opposite headers are divided into two groups of second heat transfer tubes 222 through which refrigerant flows while changing its direction as represented by the hollow arrows.

[0136] The second heat transfer tubes 222 are divided into groups such that, of the second heat transfer tubes 222, a second heat transfer tube 222 and a second heat transfer tube 222 belong to the same group if a chamber of the third header 223 to which these second heat transfer tubes 222 are connected at one end, and a chamber of the fourth header 224 to which these second heat transfer tubes 222 are connected at the other end are the same between these second heat transfer tubes 222, and belong to different groups if these chambers are different between these second heat transfer tubes 222. In FIG. 16, the respective numbers of second heat transfer tubes 222 in individual groups into which the second heat transfer tubes 222 are divided are denoted by $n_{2,1}$ and $n_{2,2}$.

[0137] The number of second heat transfer tubes 222 in each individual group is squared and summed up, and the sum total is divided by the total number of second heat transfer tubes 222 in all groups to obtain a mean number of branches N2 in the second heat exchanger 22. This can be given by the following mathematical expression: $N2 = \Sigma(n_{2,k} \times n_{2,k})/\Sigma n_{2,k}$. In the example illustrated in FIG. 16, as for the second heat exchanger 22 with a total of 21 second heat transfer tubes 222, the number of turns is 1, and the number of groups is 2. The sum total of the squares of the numbers of second heat transfer tube 222 in individual groups is 221, and the mean number of branches N2 is approximately 10.5.

[0138] Next, an investigation was made into what effect the length L1 of the first heat transfer tube of the first heat exchanger 21 and the length L2 of the second heat transfer tube of the second heat exchanger 22 have on the reduction of refrigerant, and how these lengths affect heat exchanger performance. ΔMg denotes the heat exchanger refrigerant-saving effect for condenser mode operation at 50 % load for a case where the length L1 of the first heat transfer tube and the length L2 of the second heat transfer tube are equal. Gaε denotes the heat exchanger performance for evaporator operation mode at 50 % load. The product of ΔMg and Gaε is defined as a figure of merit FM. A heat exchanger with a large figure of merit FM is superior from the viewpoints of the refrigerant saving effect and the figure of merit.

[0139] FIG. 17 is a characteristic diagram illustrating the figure of merit FM with respect to the configuration of refrigerant channels in the heat exchanger 2 according to Embodiment 3. The vertical axis in FIG. 17 represents the figure of merit FM. A test was conducted in which the first heat exchanger 21 and the second heat exchanger 22 are disposed around the rotation axis of the indoor fan 13b, and R32 is used as a refrigerant. FIG. 17 illustrates, with L1/N1 representing the ratio of the length L1 of the first heat transfer tube to the mean number of branches N1, and L2/N2 representing the ratio of the length L2 of the second heat transfer tube to the mean number of branches N2, how the figure of merit FM changes with respect to the ratio between the two ratios, (L1/N1) / (L2/N2), that is, (L1/N1) $\times$ (N2/L2), provided that L1 > L2.

[0140] As is apparent from FIG. 17, the figure of merit FM was found to have the maximum value when (L1/N1) $\times$ (N2/L2) is in the range between 2 and 3. In FIG. 17, the maximum value of the figure of merit FM is defined as a reference of 100 %. If the number and length of heat transfer tubes are the same between the first heat exchanger 21 and the second heat exchanger 22, then (L1/N1) $\times$ (N2/L2) = 1. It is apparent from FIG. 17 that, as compared with such a case, the figure of merit FM can be increased by 1.5 times or more through adjustment of the mean number of branches and the length.

[0141] It was found that even a value of (L1/N1) $\times$ (N2/L2) in the range from 1.3 to 5.2 provides a level of performance greater than or equal to 80 % of the maximum value, indicating a significant improvement in the figure of merit FM. It is further preferable to set (L1/N1) $\times$ (N2/L2) to a value in the range from 1.4 to 4.5, in which case a level of performance greater than or equal to 90 % of the maximum value can be achieved. Although increasing L1/N1 relative to L2/N2, that is, increasing L1 or decreasing N1 improves the refrigerant saving effect, increasing L1/N1 too much results in decreased heat exchange performance. Further, it is considered that as the first heat exchanger 21 and the second heat exchanger 22 become more similar in configuration and thus (L1/N1) $\times$ (N2/L2) approaches 1, the refrigerant saving effect decreases.

[0142] If the refrigerant used is changed from one kind to another, then the influence that N1 and N2 exert on the figure of merit FM changes slightly in dependence on the operating refrigerant pressure P and the amount of change in latent heat ΔH. However, the influence is small as long as the ratio between N1 and N2 remains the same. For example, it was confirmed that even if the refrigerant used is changed from R32 to R410A, or to another refrigerant with a lower gas density than these refrigerants, such as an olefin-based refrigerant, propane, or dimethyl ether, the relative change in the ratio of N2 to N1 at which the figure of merit FM peaks is small, being less than or equal to 8 %. It can be therefore expected that the above-mentioned range of (L1/N1) $\times$ (N2/L2), which was observed to be effective for the refrigerant R32, is also effective in improving the figure of merit FM even if the refrigerant used is changed to a different kind of refrigerant.

[0143] Even when the flow of air that has passed through the first heat exchanger 21, and the flow of air that has passed through the second heat exchanger 22 are at different temperatures, these flows of air are mixed together by the indoor fan 13b. This leads to enhanced performance per unit temperature of air provided to an indoor space.

Embodiment 4

[0144] In Embodiment 4, reference will be made to the relationship between the indoor heat exchanger 10 and the indoor fan 13b in the indoor unit 202 of the air-conditioning apparatus 200 according to Embodiment 1. In Embodiment 4, an axial-flow fan is employed as the indoor fan 13b. The air-conditioning apparatus 200 and the indoor heat exchanger 10 are similar in configuration to those in Embodiment 1, and thus will not be described in further detail. Elements in Embodiment 4 that are similar or corresponding to those in Embodiment 1 will be designated by the same reference signs.

[0145] FIG. 18 is a perspective view of the indoor unit 202 according to Embodiment 3. As illustrated in FIG. 18, the indoor unit 202 incorporates, as the indoor fan 13b, an axial-flow fan that operates at low pressure and high air flow rate, such as a propeller fan. The indoor fan 13b generates an air flow that travels in the direction of the rotation axis 18 from an air inlet 35 toward an air outlet 36.

[0146] In the indoor heat exchanger 10, the first header 213 and the second header 214 of the first heat exchanger 21 are positioned to extend in a direction parallel to a direction orthogonal to the rotation axis 18 of the indoor fan 13b. In the second heat exchanger 22, the third header 223 and the fourth header 224 are positioned to extend in a direction parallel to a direction orthogonal to the rotation axis 18 of the indoor fan 13b. That is, the first header 213, the second header 214, the third header 223, and the fourth header 224 extend in a direction tangential to a circle centered on the rotation axis 18 of the indoor fan 13b. As seen in the direction of the rotation axis 18, the first heat exchanger 21 and the second heat exchanger 22 are disposed at locations around the rotation axis 18 that do not overlap each other. The angular range within which the first heat exchanger 21 is located around the rotation axis 18 differs from the angular range within which the second heat exchanger 22 is located around the rotation axis 18.

[0147] FIG. 19 is a diagram of a B-B cross-section of the indoor unit 202 illustrated in FIG. 18. In FIG. 19, a straight line F connects the second header 214 of the first heat exchanger 21, and the fourth header 224 of the second heat exchanger 22. A lowermost part G represents a height position of each of the first heat exchanger 21 and the second heat exchanger 22 in the vertical direction 31. In FIG. 19, the height position of the straight line F is defined as 100 %, and the height position of the lowermost part G is defined as 0 %.

[0148] As illustrated in FIG. 19, the first heat exchanger 21 and the second heat exchanger 22 are disposed at different circumferential locations about an intersection 45 of the straight line F and the rotation axis 18, as seen in a cross-section passing through the rotation axis 18 of the indoor fan 13b and perpendicular to a direction in which the heat exchangers extend.

[0149] As described above, the first heat exchanger 21 and the second heat exchanger 22 are disposed side-by-side with respect to the air flow. As compared with disposing these heat exchangers in series with respect to the air flow, the above-mentioned configuration leads to decreased static pressure of the air flow, enhanced air flow rate, and improved heat transfer. This makes it possible to, during condenser mode operation of the indoor heat exchanger 10, reduce formation of subcooled refrigerant regions, and consequently reduce refrigerant density to thereby achieve refrigerant saving.

[0150] FIG. 20 is a diagram illustrating the flow velocity distribution of an air flow through the indoor unit 202 illustrated in FIG. 19. In FIG. 20, the vertical axis represents height position in the vertical direction 31 within the indoor unit 202 from the lowermost part G to the straight line F, and the horizontal axis represents air velocity.

[0151] As illustrated in FIG. 20, if the indoor fan 13b is an axial-flow fan, the variability in air velocity in the vertical direction 31 increases due to the distance between the indoor fan 13b and the indoor heat exchanger 10.

[0152] In the indoor heat exchanger 10, the first header 213, the second header 214, the third header 223, and the fourth header 224 are positioned to extend in a direction tangential to a circle centered on the rotation axis 18. The first heat transfer tube 212 of the first heat exchanger 21, and the second heat transfer tube 222 of the second heat exchanger 22 are each located at one end at the height of the straight line F, and located at the other end at the height of the lowermost part G.

[0153] Consequently, there is no difference among the first heat transfer tubes 212 in the rate of the air flow around the first heat transfer tubes 212, and likewise there is no difference among the second heat transfer tubes 222 in the rate of the air flow around the second heat transfer tubes 222. As a result, the difference in the amount of heat exchange among the first heat transfer tubes 212, and the difference in the amount of heat exchanger among the second heat transfer tubes 222 are reduced. This makes it possible to reduce formation of subcooled regions during condenser mode operation, and improve performance during condenser mode operation or evaporator mode operation. Therefore, both refrigerant saving and enhanced performance can be achieved.

[0154] Although the foregoing description is directed to a case where air flows from the air inlet 35 toward the air outlet 36, reversing the direction of flow from the air inlet 35 to the air outlet 36 does not affect the above-mentioned effect.

[0155] The air-conditioning apparatus 200 according to Embodiment 4 described above employs an axial-flow fan as the indoor fan 13b, and includes the first heat exchanger 21 and the second heat exchanger 22 that are disposed side-by-side with respect to the air flow. The above-mentioned configuration results in decreased static pressure of the air flow and enhanced air flow rate, which leads to reduced formation of subcooled regions during condenser mode operation. The above-mentioned configuration also results in reduced variations in heat exchange capacity among the first heat transfer tubes 212 and among the second heat transfer tubes 222. This makes it possible to achieve refrigerant saving during condenser mode operation, and improved performance during evaporator mode operation.

Embodiment 5

[0156] In Embodiment 5, reference will be made to the relationship between the indoor heat exchanger 10 and the indoor fan 13b in the indoor unit 202 of the air-conditioning apparatus 200 according to Embodiment 1. In Embodiment 5, a centrifugal fan including a scroll casing 5 is employed as the indoor fan 13b. The air-conditioning apparatus 200 and the indoor heat exchanger 10 are similar in configuration to those in Embodiment 1, and thus will not be described in further detail. Elements in Embodiment 5 that are similar or corresponding to those in Embodiment 1 will be designated by the same reference signs.

[0157] FIG. 21 is a diagram illustrating a schematic cross-section of the indoor unit 202 according to Embodiment 5. As illustrated in FIG. 21, the indoor unit 202 incorporates, as the indoor fan 13b, the indoor fan 13b including a centrifugal fan such as a multiblade fan, and the scroll casing 5 (to be referred to as "casing" hereinafter) that accommodates the centrifugal fan. An example of such a centrifugal fan is a sirocco fan. Atypical centrifugal fan includes a plurality of blades disposed in a cylindrical form. With respect to the rotation angle about the rotation axis of the centrifugal fan, the casing 5 has a rotation angle position at which the casing 5 is at its closest distance to the blades, with the distance from the blades gradually increasing from this position in the direction of blade rotation.

[0158] A position where the casing 5 is at its closest distance to the blades is defined as a winding start position 19. That is, as seen in the rotation axis direction, the scroll casing 5 has an outer shape such that the distance from the outer circumference of the rotating blades inside the scroll casing 5 is shortest at the winding start position 19, with the distance from the outer circumference of the rotating blades gradually increasing as the scroll casing extends in the rotation direction of the blades. The indoor fan 13b sucks in air in the direction of the rotation axis of the indoor fan 13b. The casing 5 has an air outlet through which air is blown out tangentially to the direction of blade rotation before completion of one revolution in the direction of blade rotation from the winding start position 19. Viewing the casing 5 in the direction of blade rotation will be hereinafter referred to as viewing the casing 5 in a winding direction 32.

[0159] The winding start position 19 is located immediately adjacent to the air outlet in the winding direction 32. Accordingly, as viewed in the rotation axis direction, the winding start position 19 represents where the casing 5 is constricted at an acute angle. As such, the winding start position 19 is also referred to as tongue. In FIG. 21, a position H is where the first heat exchanger 21 is at its closest distance to the casing 5. A position I is where the second heat exchanger 22 is at its closest distance to the casing 5. FIG. 22 is a cross-sectional diagram illustrating a schematic A-A cross-section of the indoor unit 202 according to Embodiment 5.

[0160] With regard to the indoor heat exchanger 10, the first header 213 and the second header 214 of the first heat exchanger 21 are positioned to extend in a direction parallel to the direction of the rotation axis 18 of the indoor fan 13b. In the second heat exchanger 22, the third header 223 and the fourth header 224 are positioned to extend in a direction parallel to the direction of the rotation axis 18 of the indoor fan 13b. The first heat transfer tube 212 and the second heat transfer tube 222 extend in a direction orthogonal to the rotation axis of the indoor fan 13b.

[0161] In the second heat exchanger 22, as viewed in the winding direction 32 of the casing 5, the distance from the winding start position 19 of the casing 5 to the position I is less than the distance from the winding start position 19 of the casing 5 to the position H. That is, the second heat exchanger 22 is located close to the winding start position 19 of the casing 5, and the first heat exchanger 21 is located remote from the winding start position 19 of the casing 5 as viewed in the winding direction 32 of the casing 5.

[0162] In the indoor fan 13b including the casing 5, the air flow is comparatively small near the winding start position 19 of the casing 5, and increases with increasing distance from the winding start position 19. This results in high rate of air flow through the first heat exchanger 21 during condenser mode operation of the indoor heat exchanger 10, which in turn facilitates heat transfer in the first heat exchanger 21 and reduces formation of subcooled refrigerant regions in the first heat exchanger 21. As a result, refrigerant density can be reduced to thereby achieve refrigerant saving.

[0163] During evaporator mode operation of the indoor heat exchanger 10, the refrigerant pressure in the second heat exchanger 22 is on the low-pressure side, which causes condensation water to form due to the difference between the air temperature and the refrigerant temperature. In the presence of a large air flow through the second heat exchanger 22, the condensation water is blown out to an indoor space from the surface of the second fin 221. Disposing the second heat exchanger 22 at a location near the winding start position 19 of the casing 5 and upstream with respect to the air flow reduces the inertial force that causes such condensation water to be blown out from the surface of the second fin 221. This makes it possible to increase the air flow rate without causing quality degradation of the indoor heat exchanger 10, and consequently enhance the performance of the air-conditioning apparatus 200.

[0164] In the air-conditioning apparatus 200 according to Embodiment 5 described above, the second heat exchanger 22 is disposed such that the distance from the winding start position 19 of the casing 5 to the second heat exchanger 22 is less than the distance from the winding start position 19 of the casing 5 to the first heat exchanger 21. During condenser mode operation, the above-mentioned configuration results in comparatively large air flow rate through the first heat exchanger 21, which in turn results in reduced formation of subcooled regions and reduced refrigerant density. This makes it possible to achieve refrigerant saving. During evaporator mode operation, the second heat exchanger 22 is located upstream with respect to the air flow. This helps to reduce the inertial force that causes condensation water to be blown out to an indoor space, and consequently increase the air flow rate without causing quality degradation of the indoor heat exchanger 10.

[0165] As illustrated in FIG. 22, the length of the casing 5 of the fan in the direction of the rotation axis 18 is less than the length of the first heat exchanger 21 in the direction of the rotation axis 18. The casing 5 has an air inlet 5a through which air is sucked in the direction of the rotation axis 18. The first chamber 213a of the second heat exchanger 22, which is the most downstream located chamber during condenser mode operation, is displaced at least in part but desirably in its entirety relative to the casing 5 in the direction of the rotation axis 18. As described above, the first chamber 213a is disposed at a location where the casing 5 is not present in the rotational circumferential direction of the rotation axis 18 of the fan.

[0166] Accordingly, the air flow rate through the first heat transfer tube 212 and the first fin 211 that are connected to the first chamber 213a is greater than that in a region that overlaps the casing 5 in the direction of the rotation axis 18. The heat exchanger according to Embodiment 5 thus makes it possible to facilitate heat transfer for liquid refrigerant, and achieve both refrigerant saving and enhanced performance. The same effect as mentioned above can be obtained even if the indoor fan 13b includes a centrifugal fan such as a multiblade fan, a scroll casing that accommodates the centrifugal fan, and a cross-flow fan that is disposed in a part thereof.

[0167] When viewed in the direction of the rotation axis 18 of the indoor fan 13b, the first heat exchanger 21 and the second heat exchanger 22 are disposed at locations around the rotation axis 18 that do not overlap each other. The angular range within which the first heat exchanger 21 is located around the rotation axis 18 differs from the angular range within which the second heat exchanger 22 is located around the rotation axis 18. Accordingly, disposing the first heat exchanger 21 and the second heat exchanger 22 side-by-side with respect to the air flow as described above with reference to Embodiment 4 allows for decreased static pressure of the air flow, enhanced air flow rate, and improved heat transfer, as compared with disposing these heat exchangers in series with respect to the air flow. This makes it possible to, during condenser mode operation of the indoor heat exchanger 10, reduce formation of subcooled refrigerant regions, and consequently reduce refrigerant density to thereby achieve refrigerant saving.

[0168] As described above, the first heat exchanger 21 and the second heat exchanger 22 are disposed side-by-side with respect to the air flow. This results in decreased static pressure of the air flow and enhanced air flow rate, which leads to reduced formation of subcooled regions during condenser mode operation.

Industrial Applicability

[0169] The present invention is applicable to an air-conditioning apparatus including a heat exchanger capable of serving both as a condenser and as an evaporator.

List of Reference Signs

[0170]

4: partition part,
5: casing,
6: third heat transfer tube,
7: other end,
8: one end,
10: indoor heat exchanger,
11a: pipe,
11b: pipe,
11 c: pipe,
11d: pipe,
12: connection pipe,
13a: outdoor fan,
13b: indoor fan,
14: compressor,
15: four-way valve,
16: outdoor heat exchanger,
17: expansion device (pressure reducing device),
18: rotation axis,
19: winding start position of casing,
20: impeller,
21: first heat exchanger,
22: second heat exchanger,
23: third heat exchanger,
30: refrigerant flow direction,
31: vertical direction,
32: winding direction of casing,
33: rotation axis direction,
35: air inlet,
36: air outlet,
41: lowermost part,
42: lowermost part,
45: intersection,
51: gravitational force,
52: inertial force,
61: liquid-phase refrigerant,
62: gas-phase refrigerant,
71: flat-tube cross-section,
200: air-conditioning apparatus,
201: outdoor unit,
202: indoor unit,
211: first fin,
212: first heat transfer tube,
213: first header,
213a: chamber,
213b: chamber,
213c: chamber,
213d: chamber,

214: second header,
214a: chamber,
214b: chamber,
214c: chamber,
221: second fin,
222: second heat transfer tube,
223: third header,
223a: chamber,
223b: chamber,
224: fourth header,
C: corner,
D: corner,
E: corner,
F: straight line,
G: lowermost part.

Claims

1. 1. An air-conditioning apparatus in which a compressor, a condenser, a pressure reducing device, and an evaporator are connected by a pipe and in which refrigerant circulates, the air-conditioning apparatus comprising:

a heat exchanger configured to, in response to switching of directions of refrigerant flow, switch between serving as the evaporator and serving as the condenser; and
a fan configured to generate an air flow to send air to the heat exchanger,
wherein the heat exchanger includes

a first heat exchanger including

a plurality of first heat transfer tubes,
a first header extending in a horizontal direction, the first header having an internal space divided into a plurality of chambers including a first chamber and a second chamber, the first header being connected with one end of each of the plurality of first heat transfer tubes, and
a second header extending in the horizontal direction, the second header being connected with an other end of each of the plurality of first heat transfer tubes,

a second heat exchanger including

a plurality of second heat transfer tubes,
a third header extending in the horizontal direction, the third header being connected with one end of each of the plurality of second heat transfer tubes, and
a fourth header extending in the horizontal direction, the fourth header being connected with an other end of each of the plurality of second heat transfer tubes, and

a connection pipe connecting one of the first header and the second header of the first heat exchanger, and the third header of the second heat exchanger,

wherein for an operation in which the heat exchanger is made to serve as the evaporator,

the plurality of first heat transfer tubes are connected such that, after refrigerant to be evaporated enters the first chamber of the first header from the pipe, the refrigerant flows to the second header, and then flows from the second header to the second chamber of the first header,
the plurality of second heat transfer tubes are connected such that, after the refrigerant passes through the first heat exchanger, the refrigerant flows via the connection pipe into the third header of the second heat exchanger, and then flows from the third header to the fourth header, and further,
the pipe is connected such that, after the refrigerant passes through the second heat exchanger, the refrigerant is sucked into the compressor,

wherein for an operation in which the heat exchanger is made to serve as the condenser,
the pipe is connected such that, after refrigerant to be condensed passes through the second heat exchanger from the pipe, the refrigerant flows via the connection pipe into one of the plurality of chambers of the first header of the first heat exchanger, or into the second header, and after passing through the first heat exchanger, the refrigerant exits from the first chamber of the first header, and
wherein the plurality of first heat transfer tubes each have a length greater than a length of each of the plurality of second heat transfer tubes.

2. 2. The air-conditioning apparatus of claim 1,

wherein the second header and the third header each have an internal space divided into a plurality of chambers, and
wherein the connection pipe connects: one of the plurality of chambers of the first header, or one of the plurality of chambers of the second header; and one of the plurality of chambers of the third header.

3. 3. The air-conditioning apparatus of claim 2, wherein the internal space of the first header or the second header includes a number of chambers connected to the connection pipe greater than a number of chambers in the internal space of the third header that are connected to the connection pipe.

4. 4. The air-conditioning apparatus of any one of claims 1 to 3, wherein the first chamber of the first header is smaller than the second chamber.

5. 5. The air-conditioning apparatus of any one of claims 1 to 4, wherein the internal space of the third header is divided into the plurality of chambers that are equal in size.

6. 6. The air-conditioning apparatus of any one of claims 1 to 5, wherein a lowermost part of the first heat exchanger is located lower in a vertical direction than is a lowermost part of the second heat exchanger.

7. 7. The air-conditioning apparatus of any one of claims 1 to 6,

wherein the first chamber of the first header is a chamber located at one end of the first header in the horizontal direction, and
wherein the connection pipe connects: one of the plurality of chambers of the first header that is located at an other end in the horizontal direction, or one of the plurality of chambers of the second header that is located at an other end in the horizontal direction; and the third header.

8. 8. The air-conditioning apparatus of any one of claims 1 to 7, wherein when:

with the plurality of first heat transfer tubes being divided into a plurality of groups such that a first heat transfer tube and another first heat transfer tube belong to a same group if a chamber of the first header to which the first heat transfer tube and the another first heat transfer tube are connected at one end, and a chamber of the second header to which the first heat transfer tube and the another first heat transfer tube are connected at an other end are same between the first heat transfer tube and the another first heat transfer tube, and belong to different groups if a chamber of the first header to which the first heat transfer tube and the another first heat transfer tube are connected at one end, and a chamber of the second header to which the first heat transfer tube and the another first heat transfer tube are connected at an other end are different between the first heat transfer tube and the another first heat transfer tube, the first heat exchanger has a mean number of branches N1, the mean number of branches N1 being determined by summing, for all of the plurality of groups, a square of a number of the first heat transfer tubes in each of the plurality of groups to obtain a sum total, and dividing the sum total by a total number of the first heat transfer tubes in all of the plurality of groups;
with the plurality of second heat transfer tubes being divided into a plurality of groups such that a second heat transfer tube and another second heat transfer tube belong to a same group if a chamber of the third header to which the second heat transfer tube and the another second heat transfer tube are connected at one end, and a chamber of the fourth header to which the second heat transfer tube and the another second heat transfer tube are connected at an other end are same between the second heat transfer tube and the another second heat transfer tube, and belong to different groups if a chamber of the third header to which the second heat transfer tube and the another second heat transfer tube are connected at one end, and a chamber of the fourth header to which the second heat transfer tube and the another second heat transfer tube are connected at an other end are different between the second heat transfer tube and the another second heat transfer tube, the second heat exchanger has a mean number of branches N2, the mean number of branches N2 being determined by summing, for all of the plurality of groups, a square of a number of the second heat transfer tubes in each of the plurality of groups to obtain a sum total, and dividing the sum total by a total number of the second heat transfer tubes in all of the plurality of groups; and
each of the plurality of first heat transfer tubes has a length L1, and each of the plurality of second heat transfer tubes has a length L2,
$(L1/N1) \times (N2/L2)$ is in a range of 1.3 to 5.2.

9. 9. The air-conditioning apparatus of any one of claims 1 to 8,

wherein the fan is a fan with a blade that rotates around a rotation axis of the fan, and
wherein when viewed in a direction of the rotation axis, the first heat exchanger and the second heat exchanger are disposed at locations around the rotation axis that do no overlap each other.

10. 10. The air-conditioning apparatus of any one of claims 1 to 9,

wherein the fan is an axial-flow fan,
wherein the first header, the second header, the

third header, and the fourth header extend in a direction tangential to a circle centered on the rotation axis of the fan, and
wherein when seen in plan view in a plane orthogonal to the rotation axis, the first heat exchanger and the second heat exchanger are disposed at locations that do not overlap each other.

11. 11. The air-conditioning apparatus of any one of claims 1 to 9,

wherein the fan is a centrifugal fan including a scroll casing,
wherein each of the plurality of first heat transfer tubes, and each of the plurality of second heat transfer tubes extend in a direction orthogonal to a rotation axis of the fan,
wherein the first header, the second header, the third header, and the fourth header extend in a direction parallel to a direction of the rotation axis, and
wherein in a plane orthogonal to the rotation axis, as viewed in a winding direction of the scroll casing, the second heat exchanger is located closer to a winding start position of the scroll casing than is the first heat exchanger.

12. 12. The air-conditioning apparatus of any one of claims 1 to 11, wherein the first heat exchanger and the second heat exchanger are mounted in an indoor unit.

13. 13. The air-conditioning apparatus of any one of claims 1 to 12, wherein the refrigerant is an olefin-based refrigerant, propane, or dimethyl ether, and has a low gas density relative to an R32 refrigerant or an R410A refrigerant.

14. 14. The air-conditioning apparatus of any one of claims 1 to 13,

wherein the air-conditioning apparatus comprises the compressor, a use-side heat exchanger, an expansion device, and a heat-source-side heat exchanger,
wherein the compressor comprises at least one compressor, and
wherein at least one of the use-side heat exchanger or the heat-source-side heat exchanger includes the first heat exchanger and the second heat exchanger.

FIG. 1

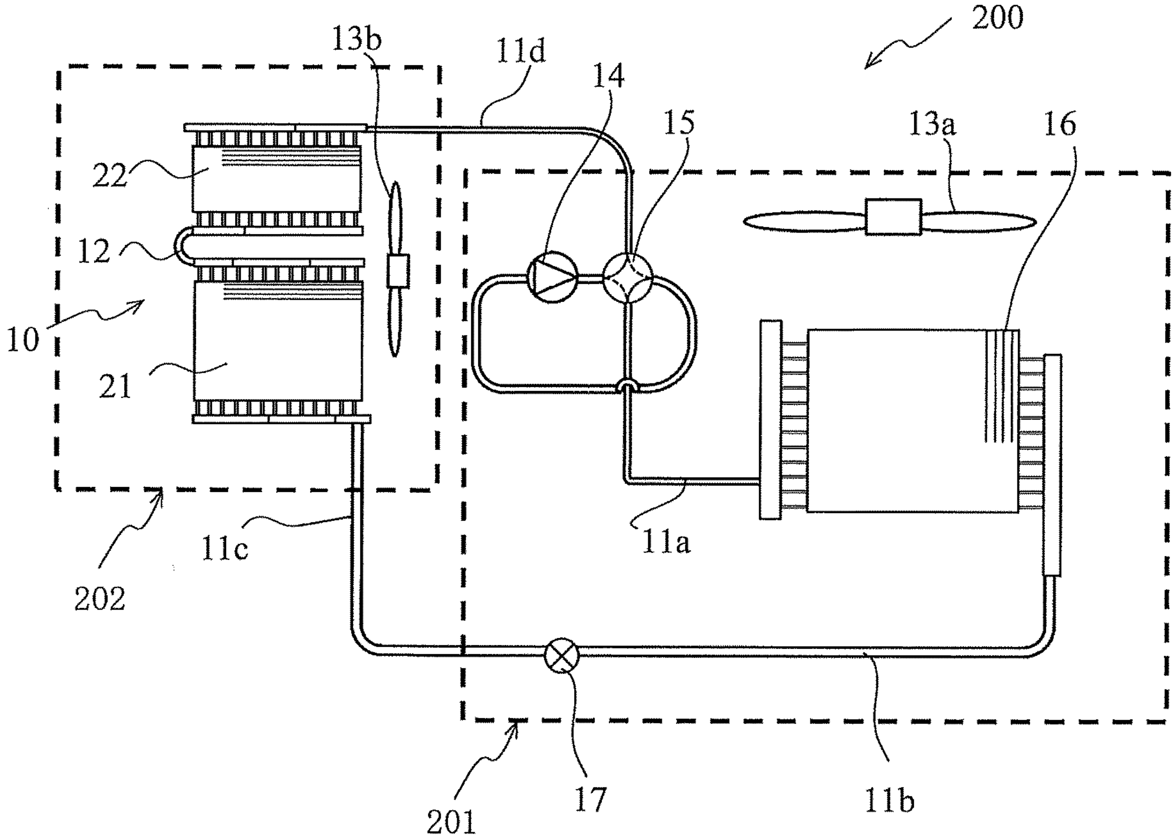
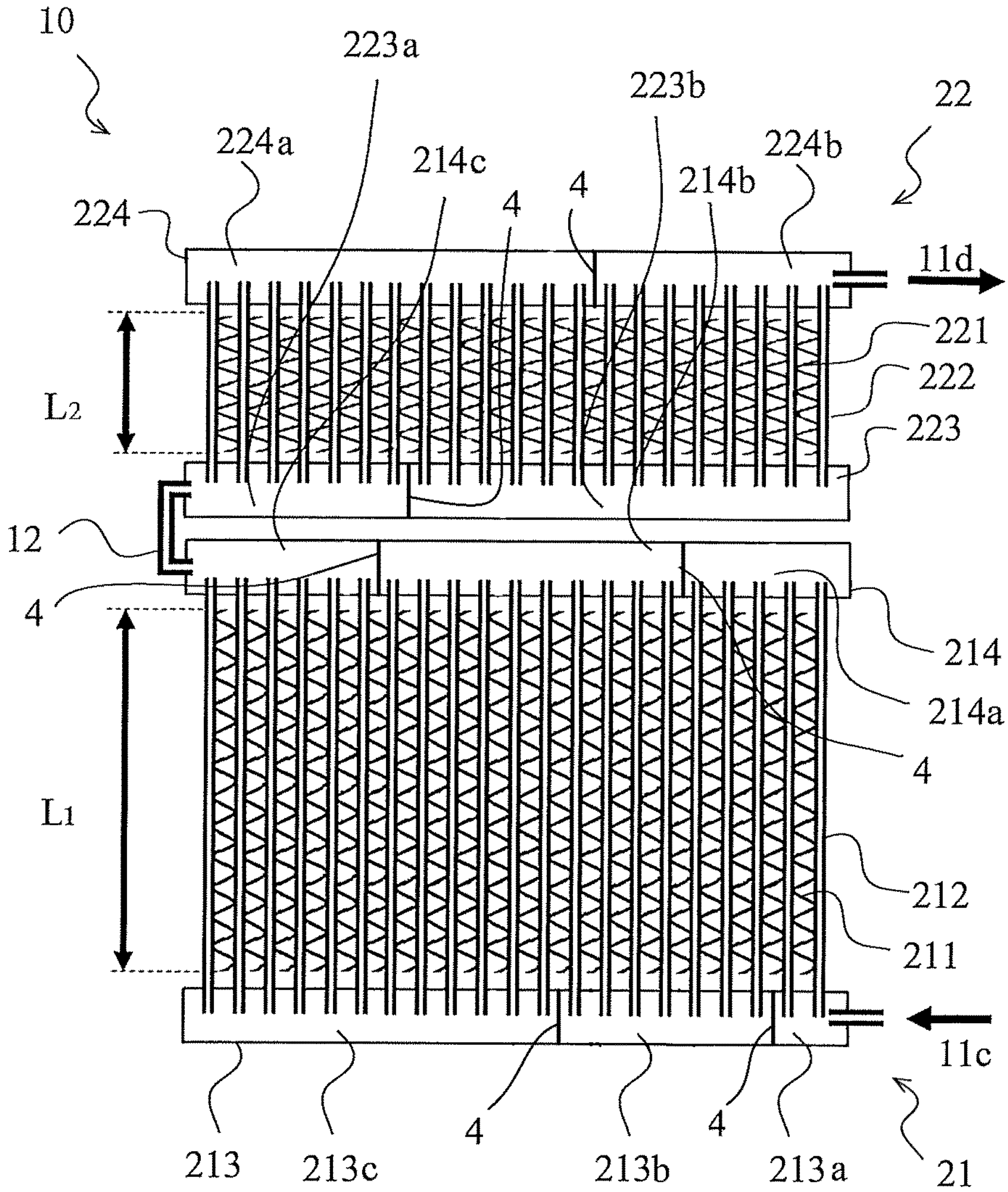


FIG. 2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L2
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L1
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213b
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213a
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FIG. 3

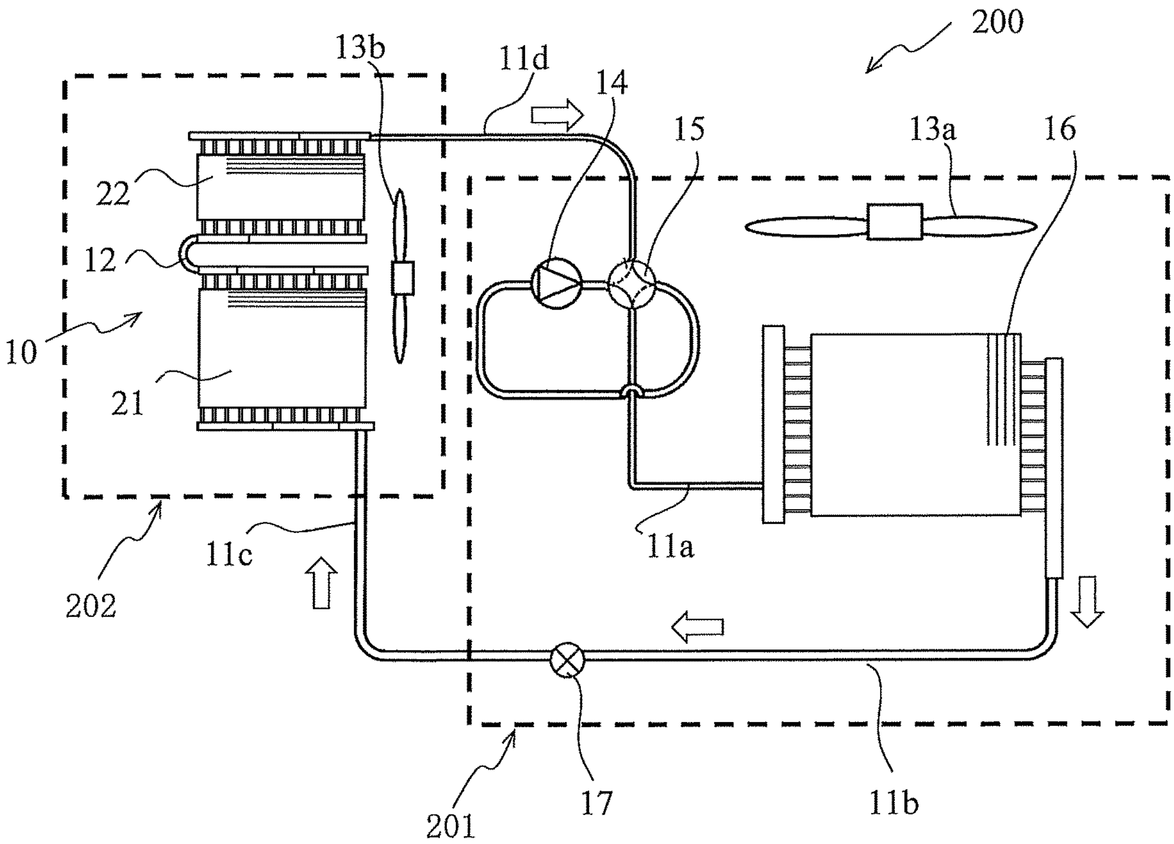
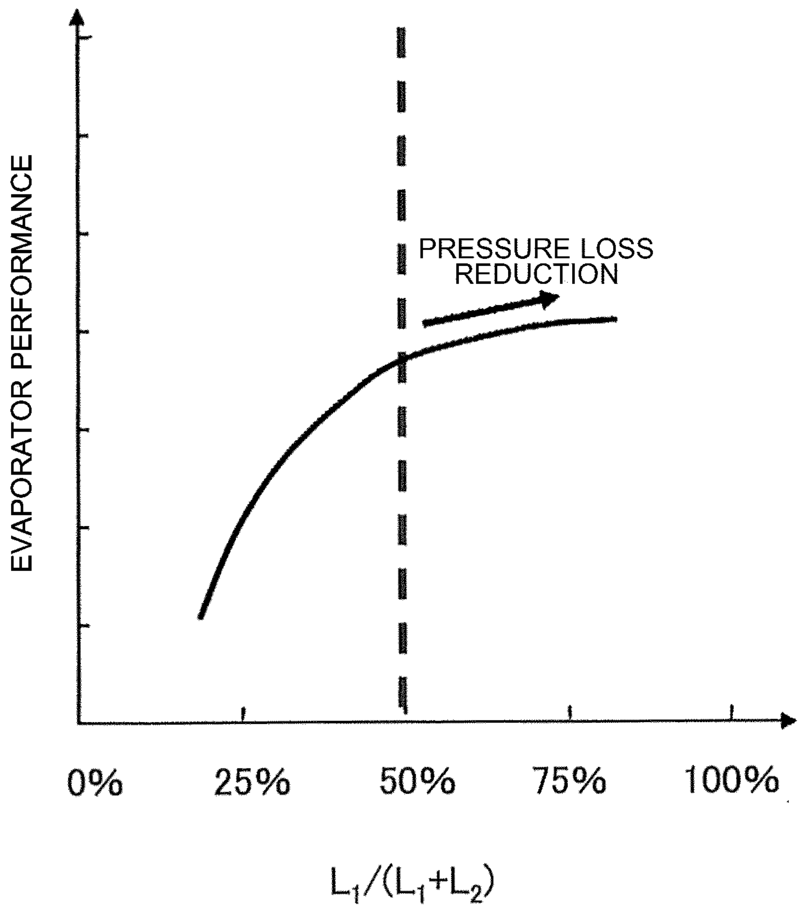


FIG. 4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50%
75%
100%
$L_1/(L_1+L_2)$

FIG. 5

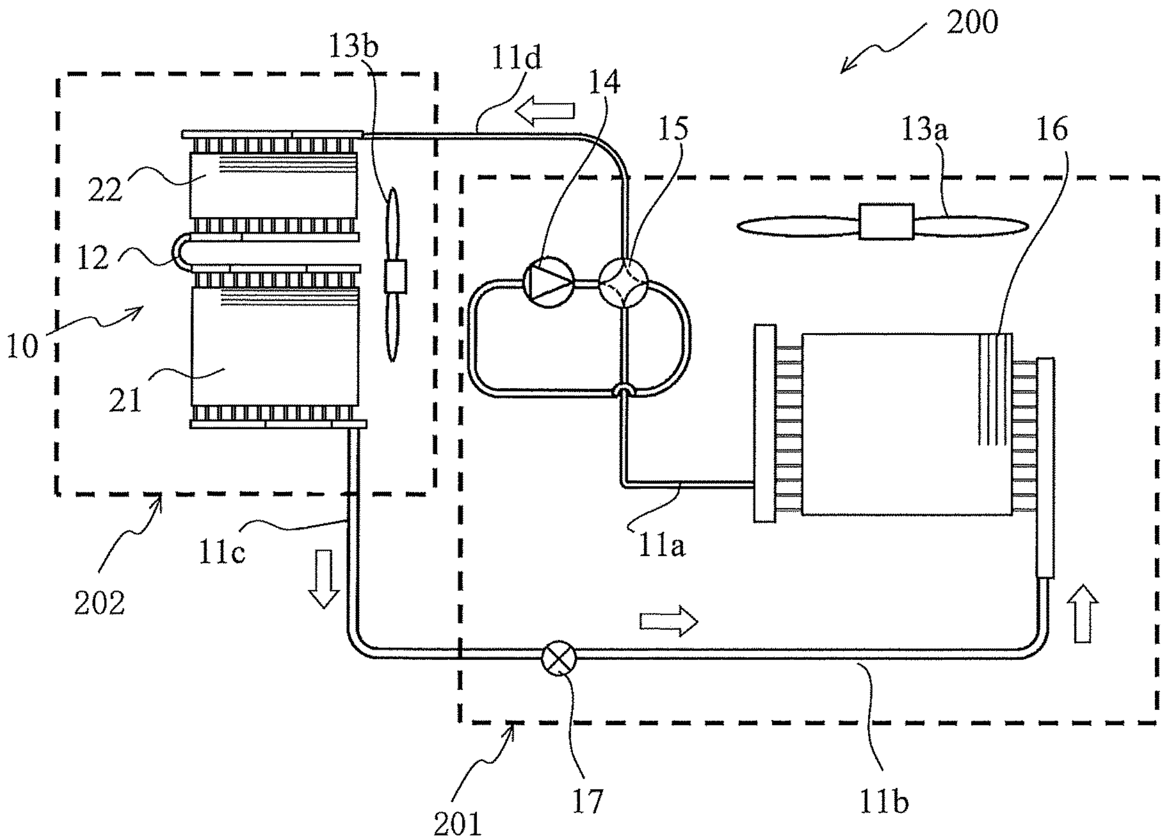
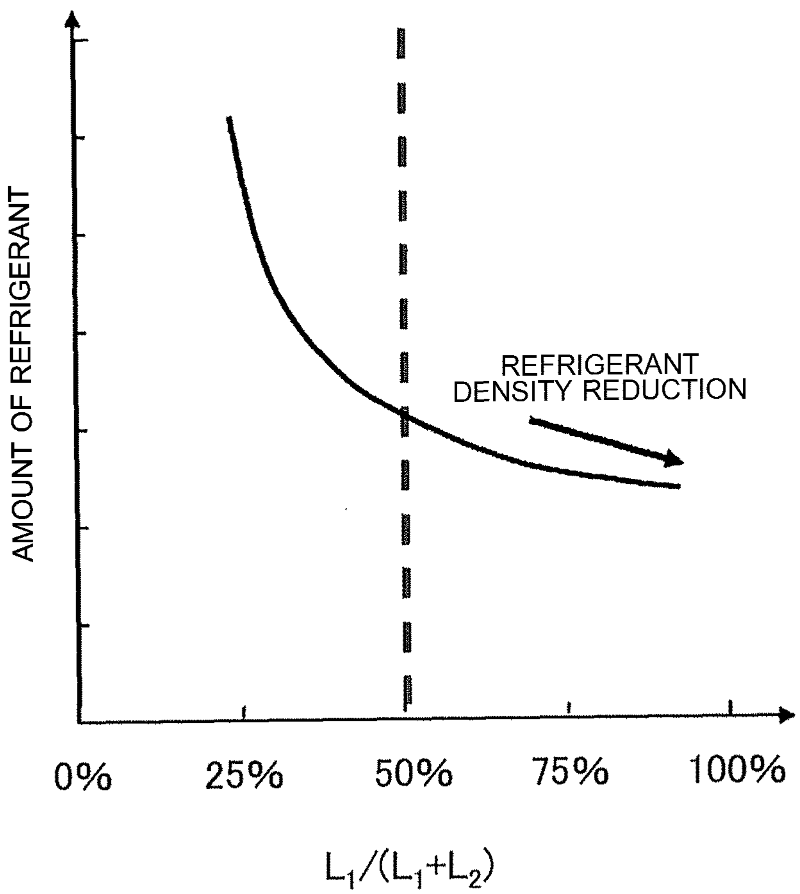


FIG. 6


AMOUNT OF REFRIGERANT
REFRIGERANT DENSITY REDUCTION
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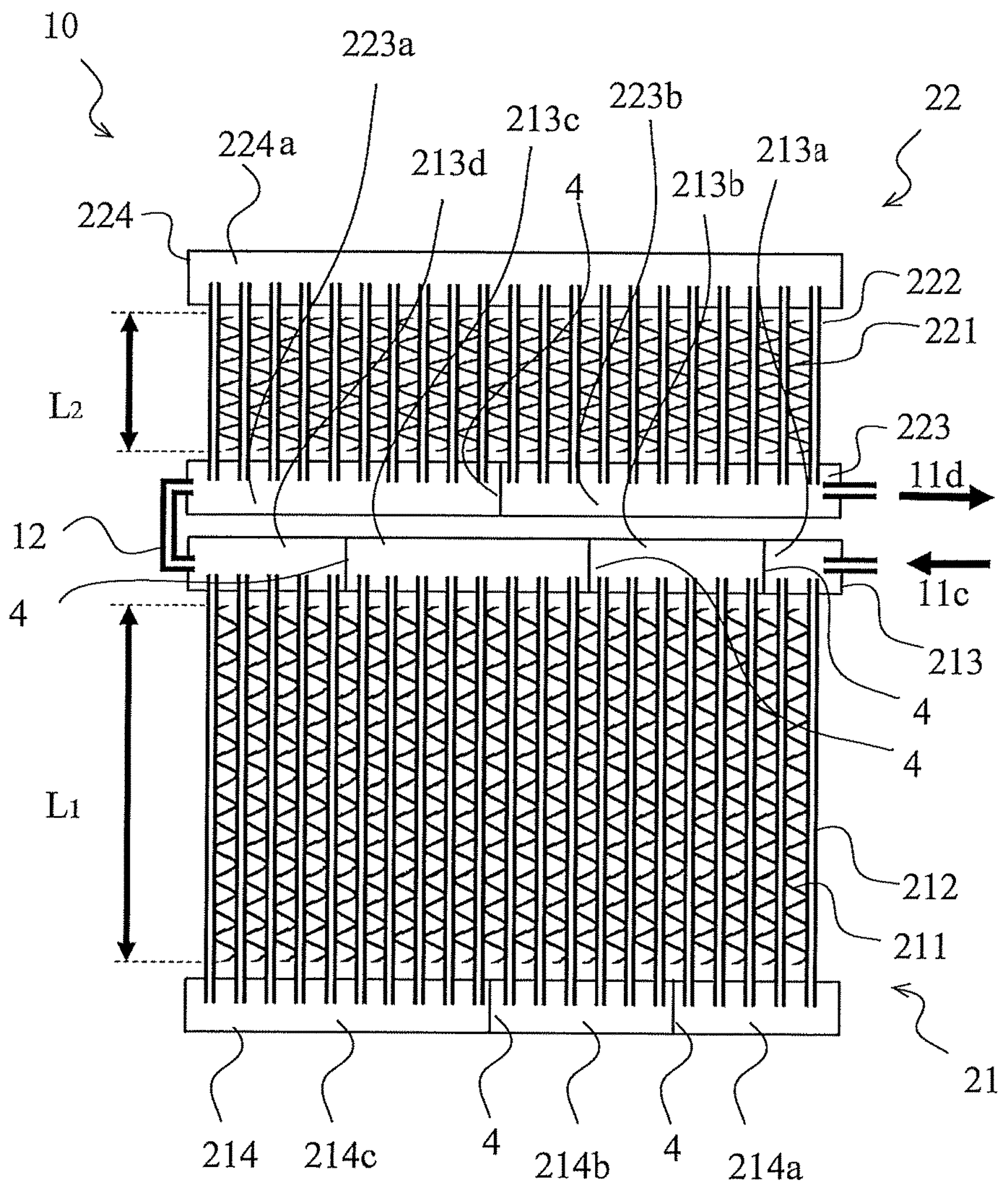
25%
50%
75%
100%
$L_1/(L_1+L_2)$

FIG. 7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L2
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L1
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214c
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214b
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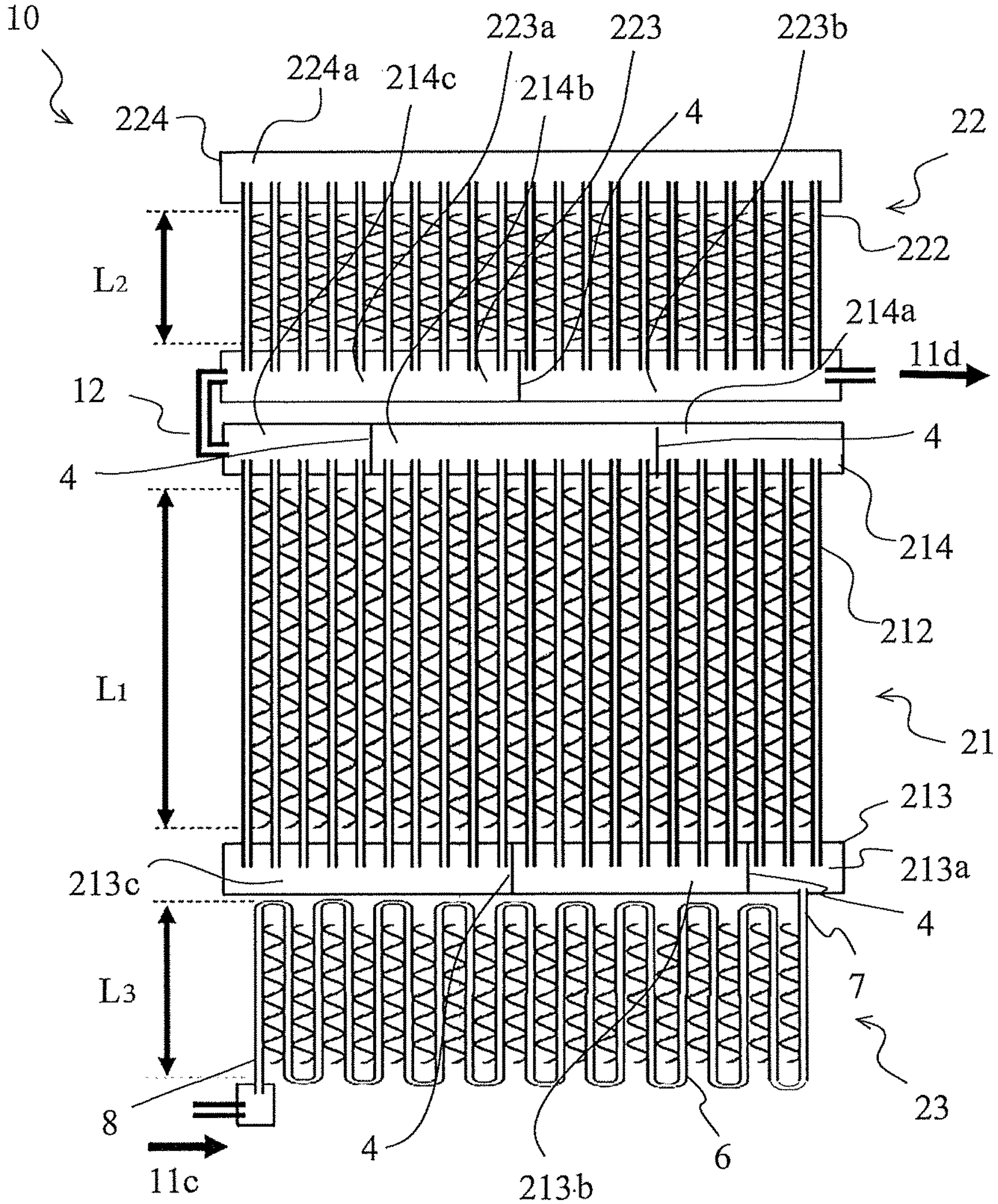
214a

FIG. 8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L2
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L3
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23
8
4
213b
6
11c

FIG. 9

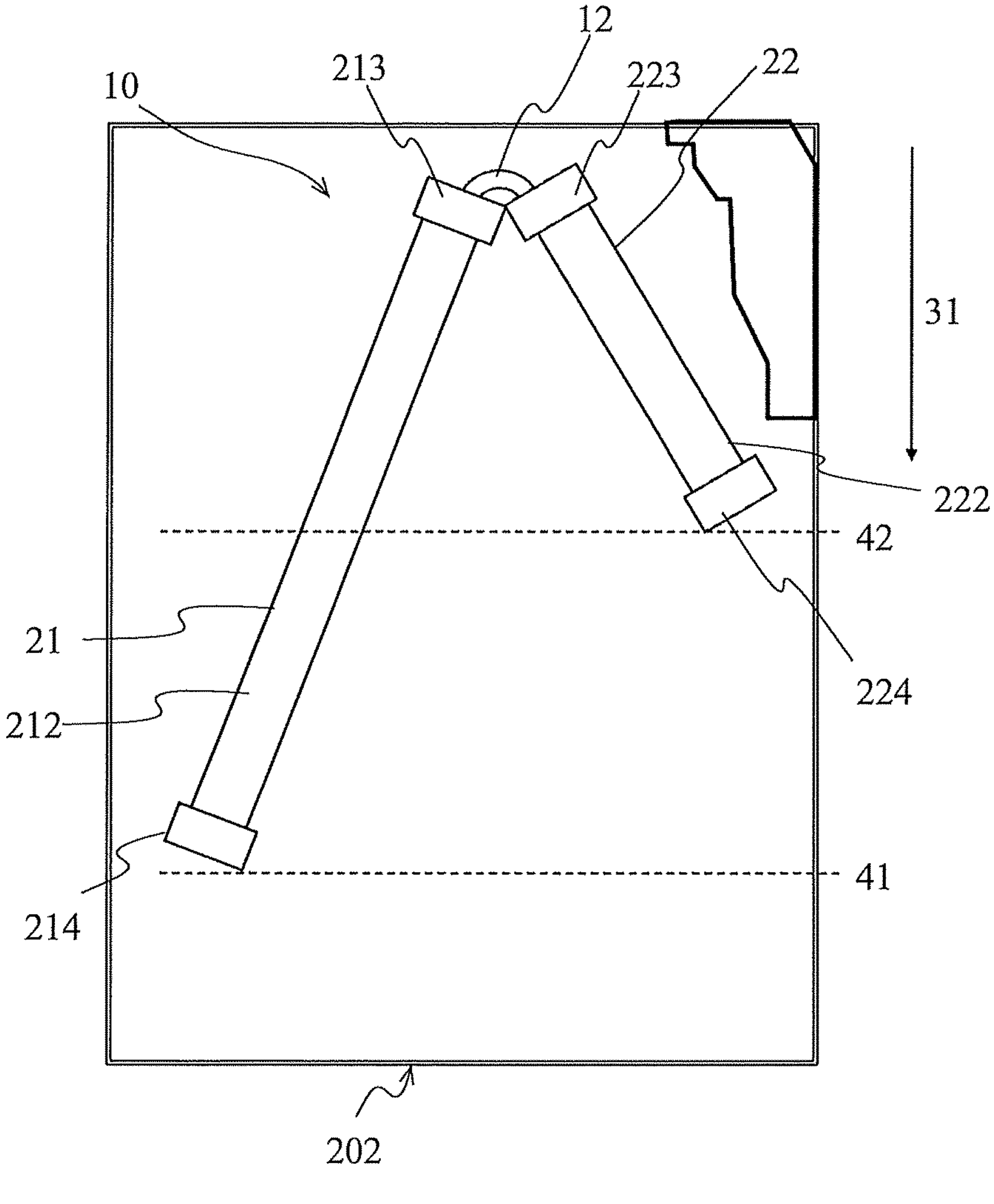

FIG. 10

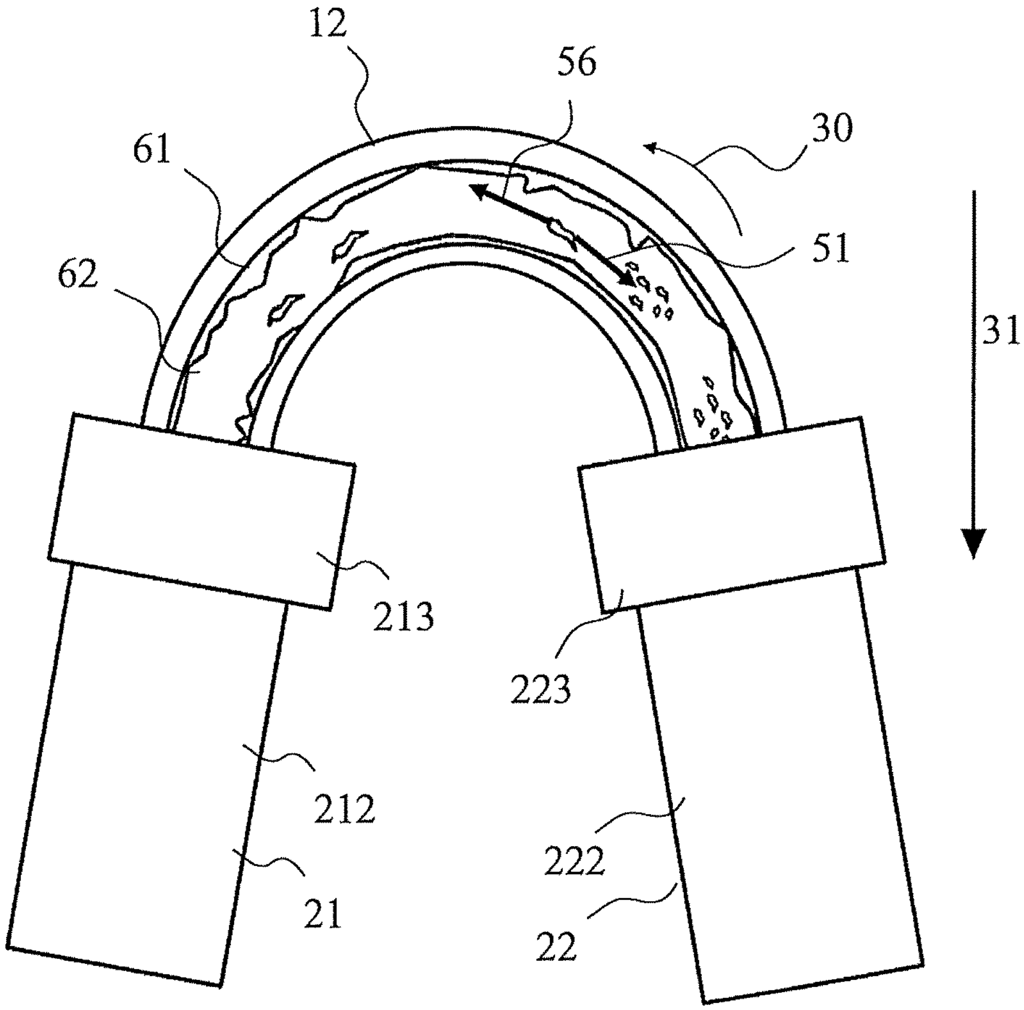

FIG. 11

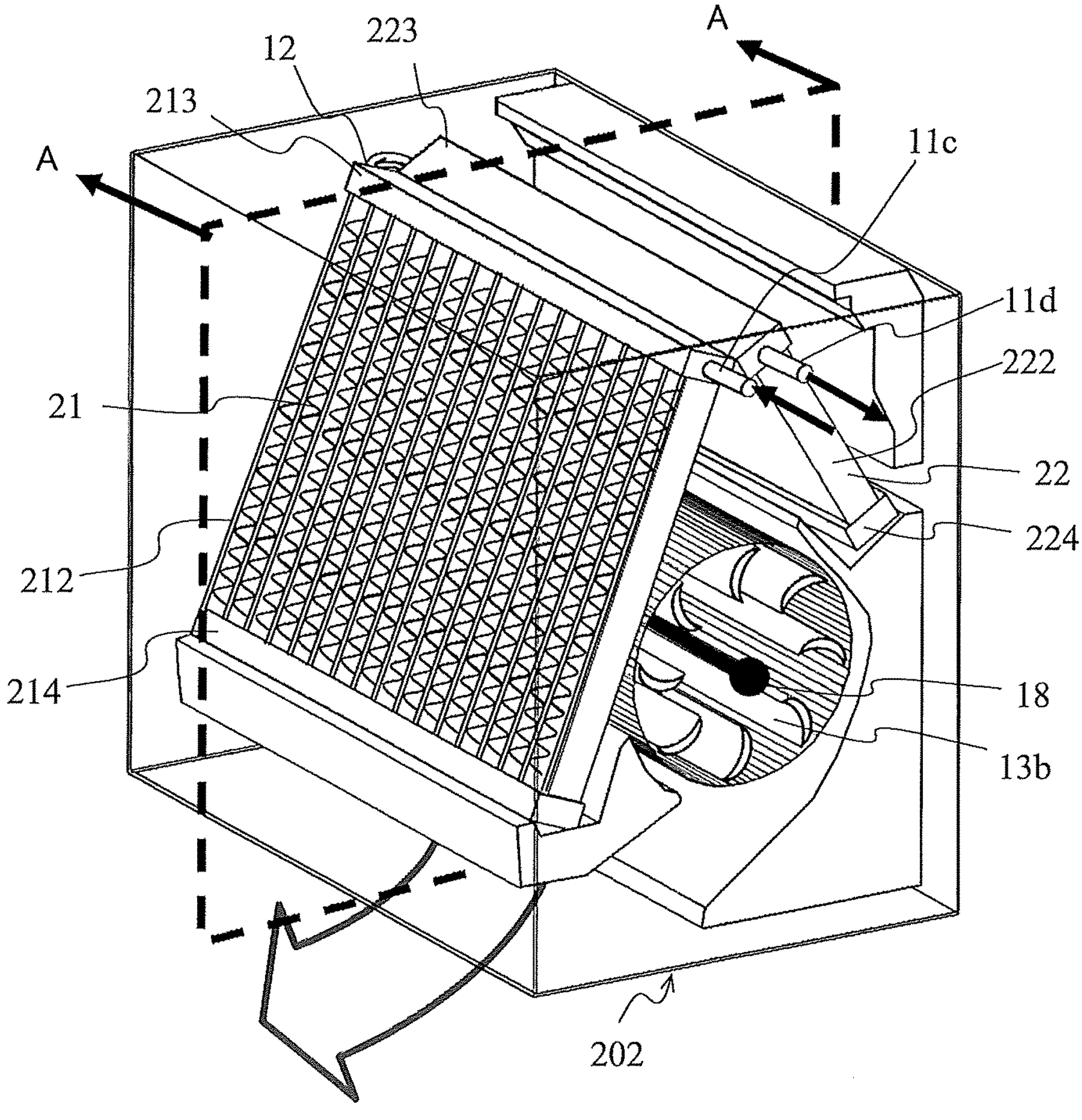

FIG. 12

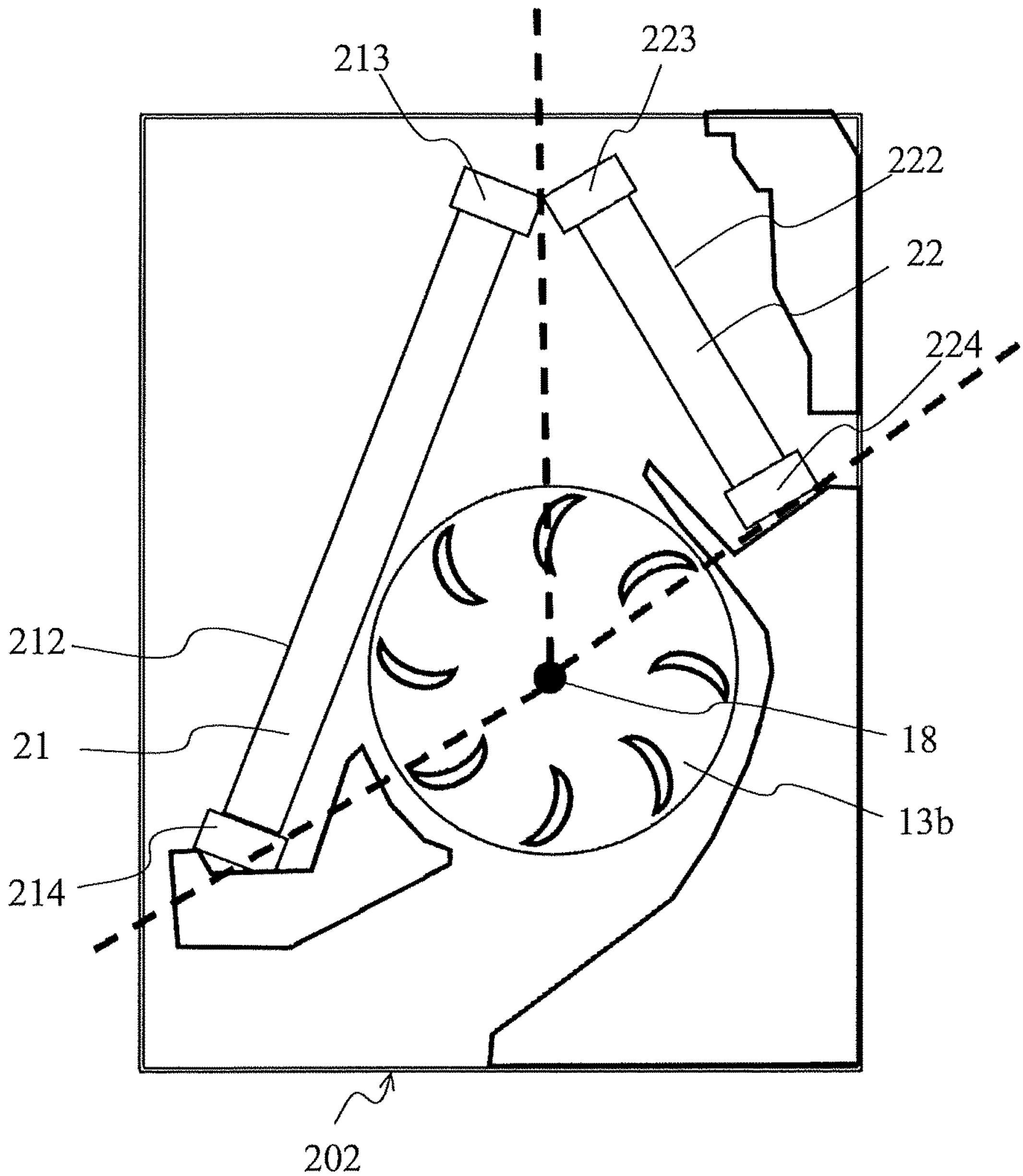

FIG. 13

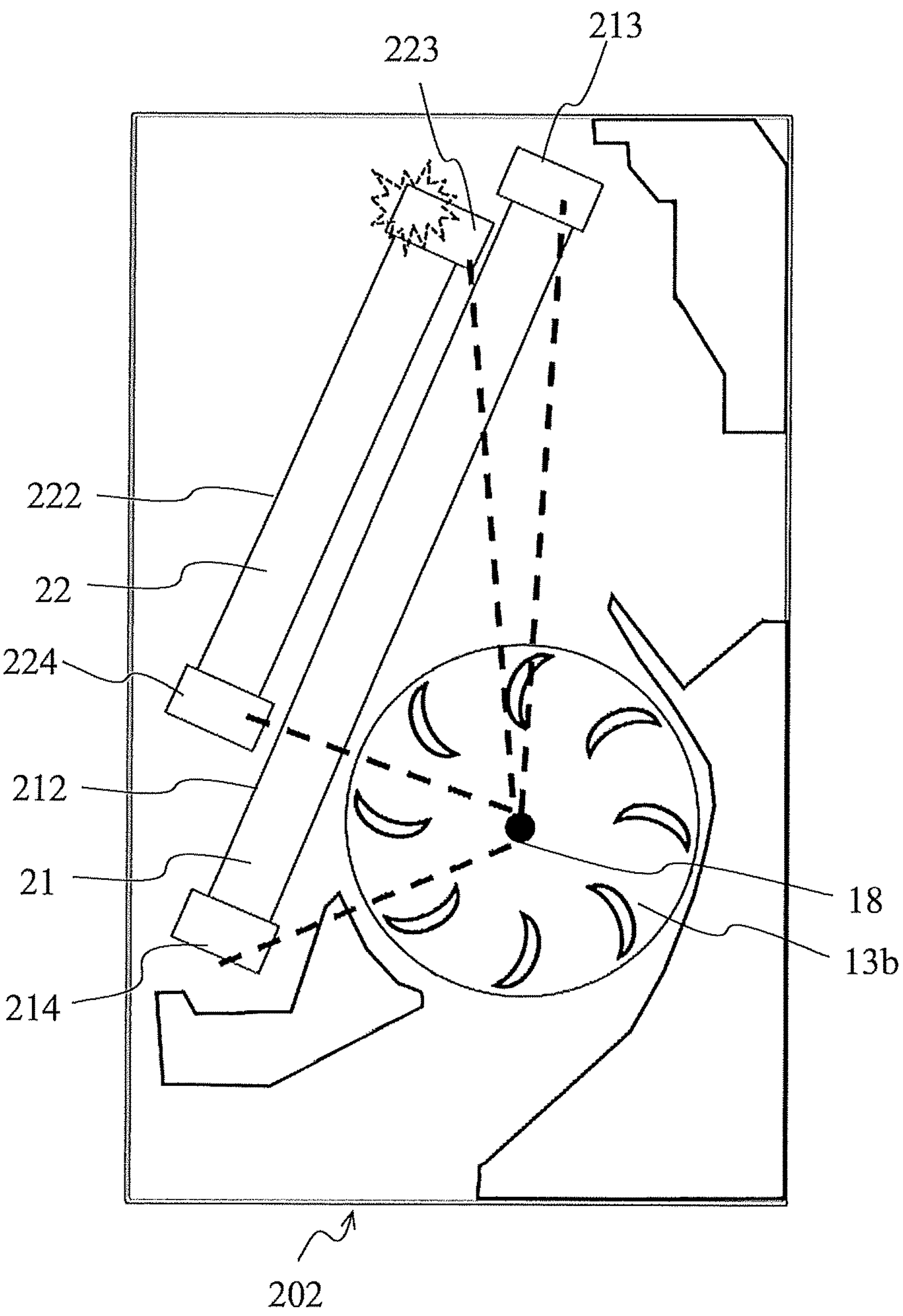

FIG. 14

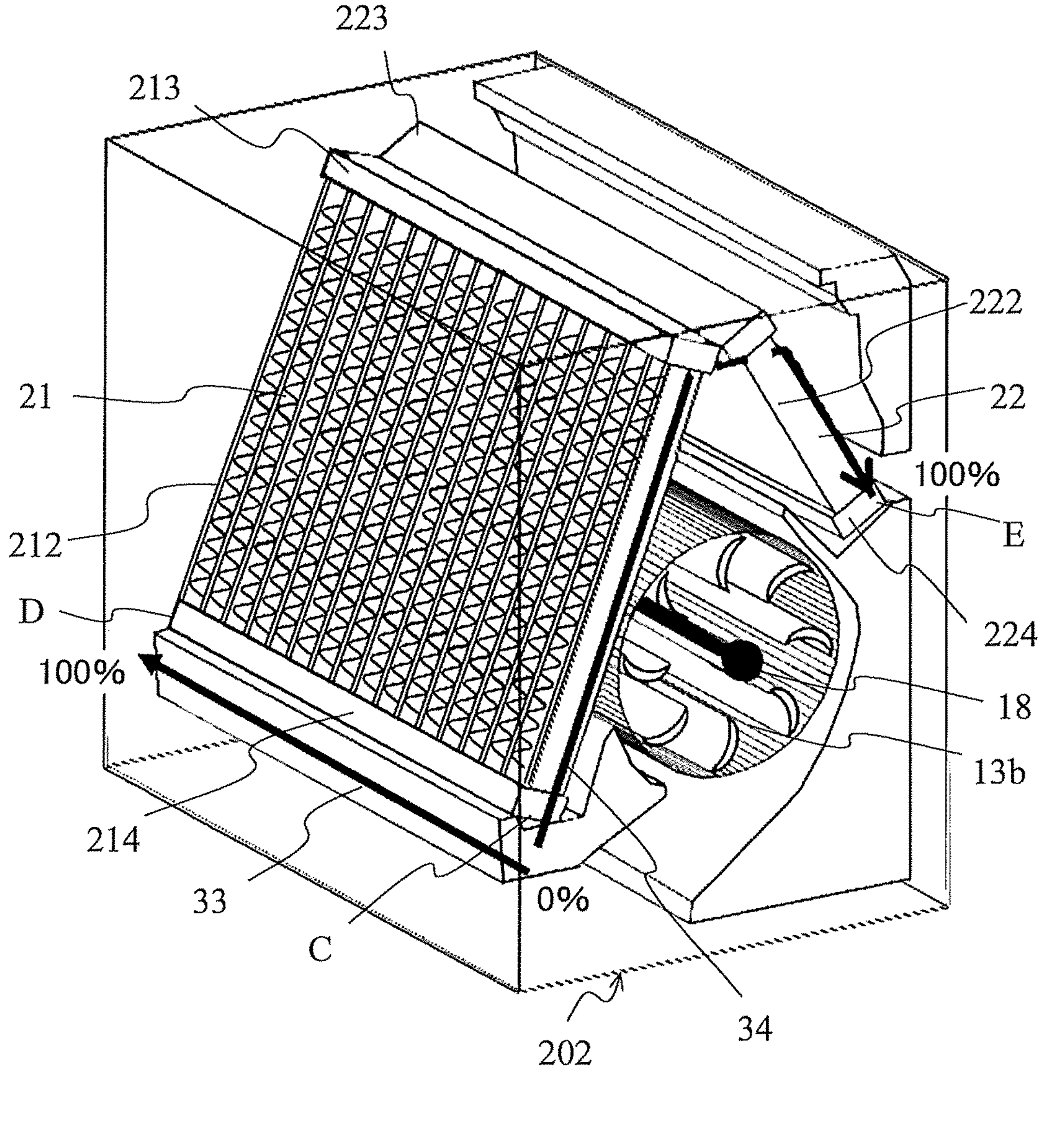

FIG. 15

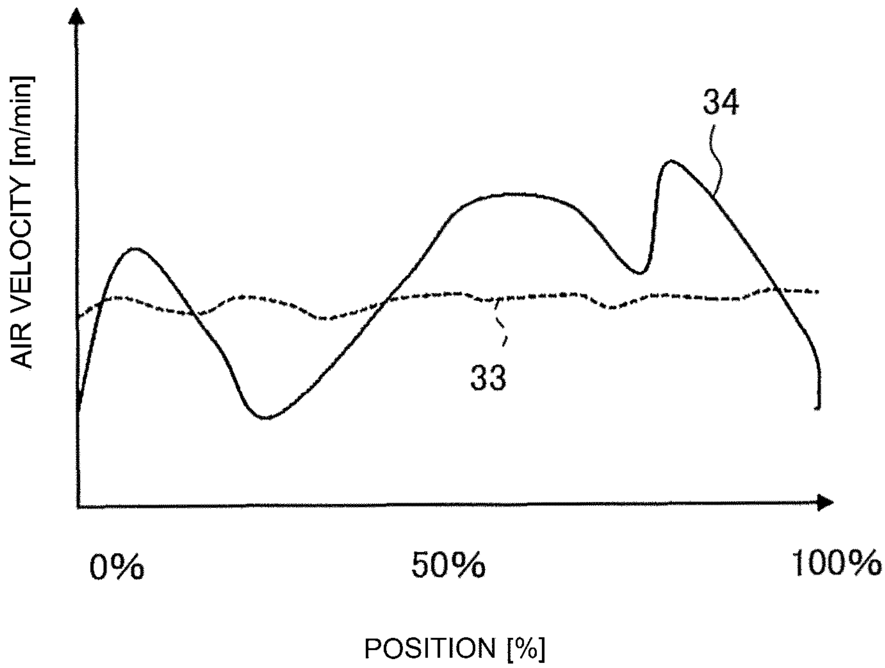

FIG. 16

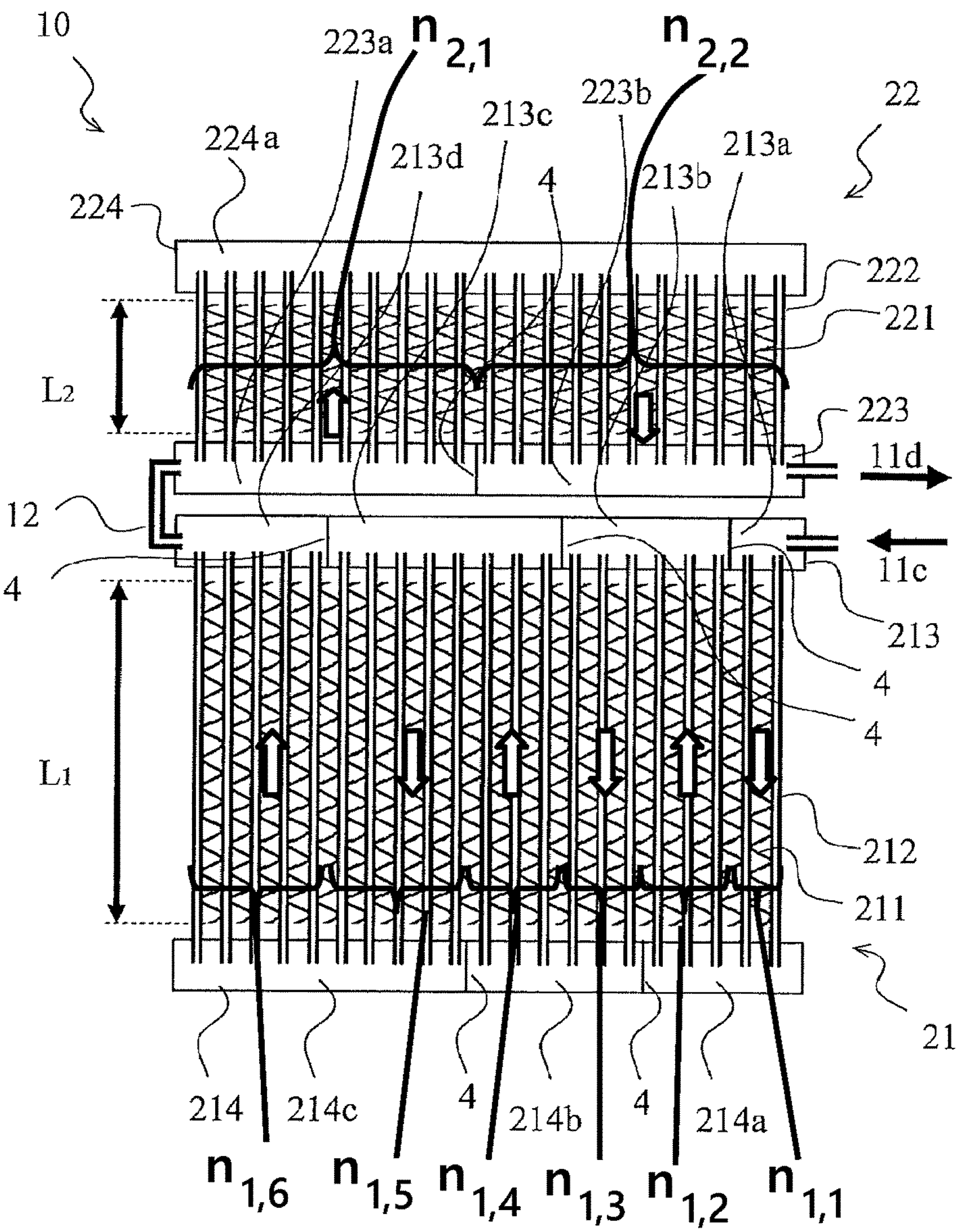
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FIG. 17

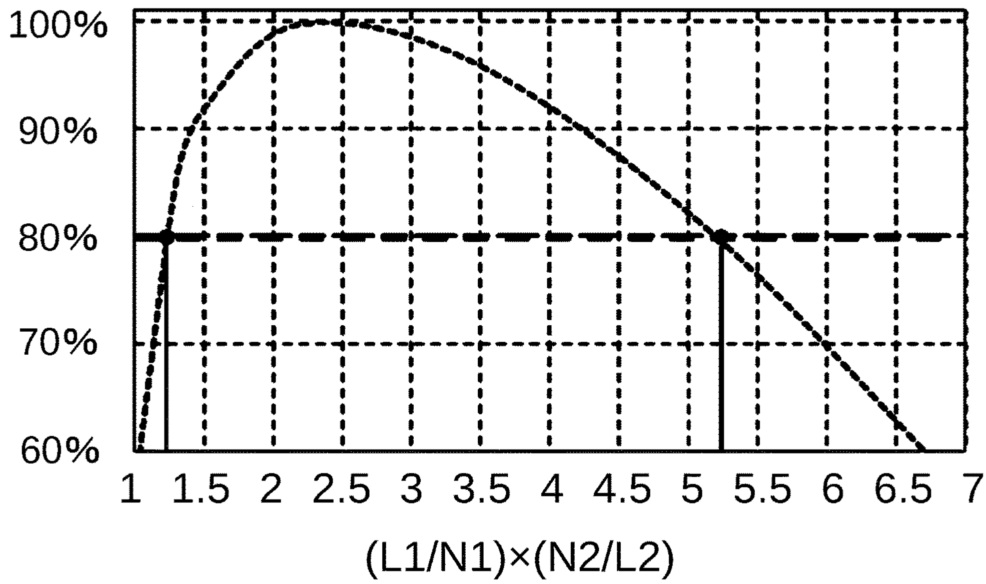


FIG. 18

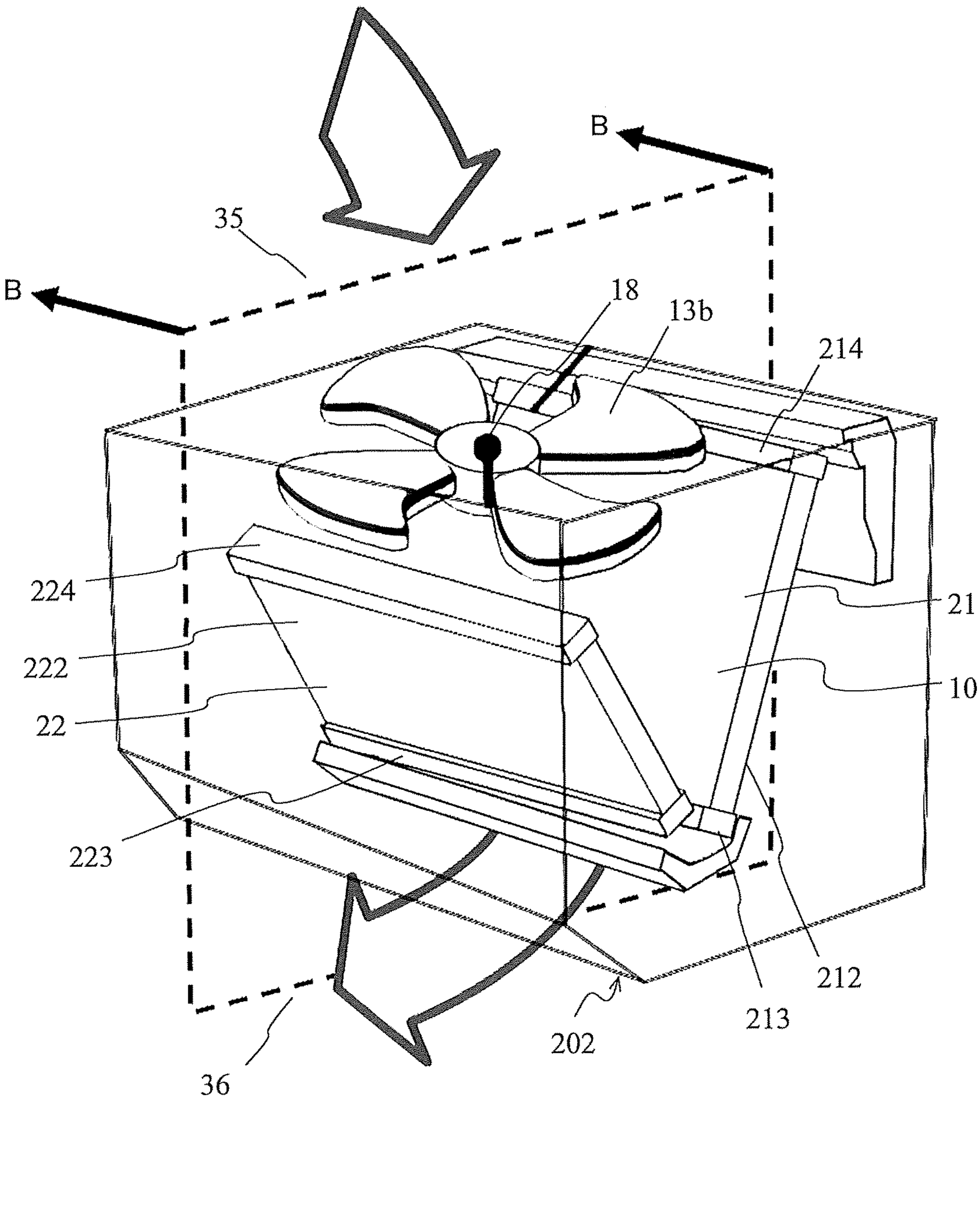


FIG. 19

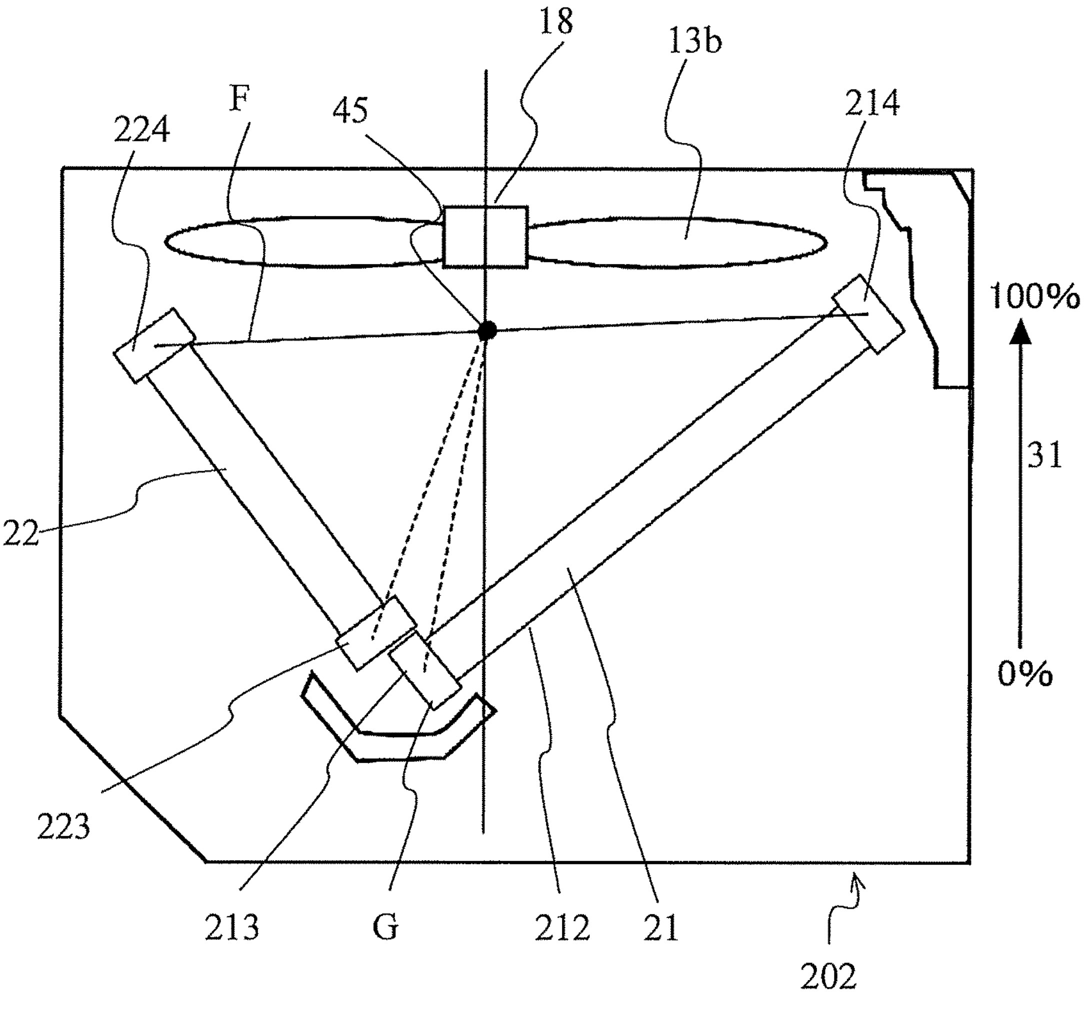


FIG. 20

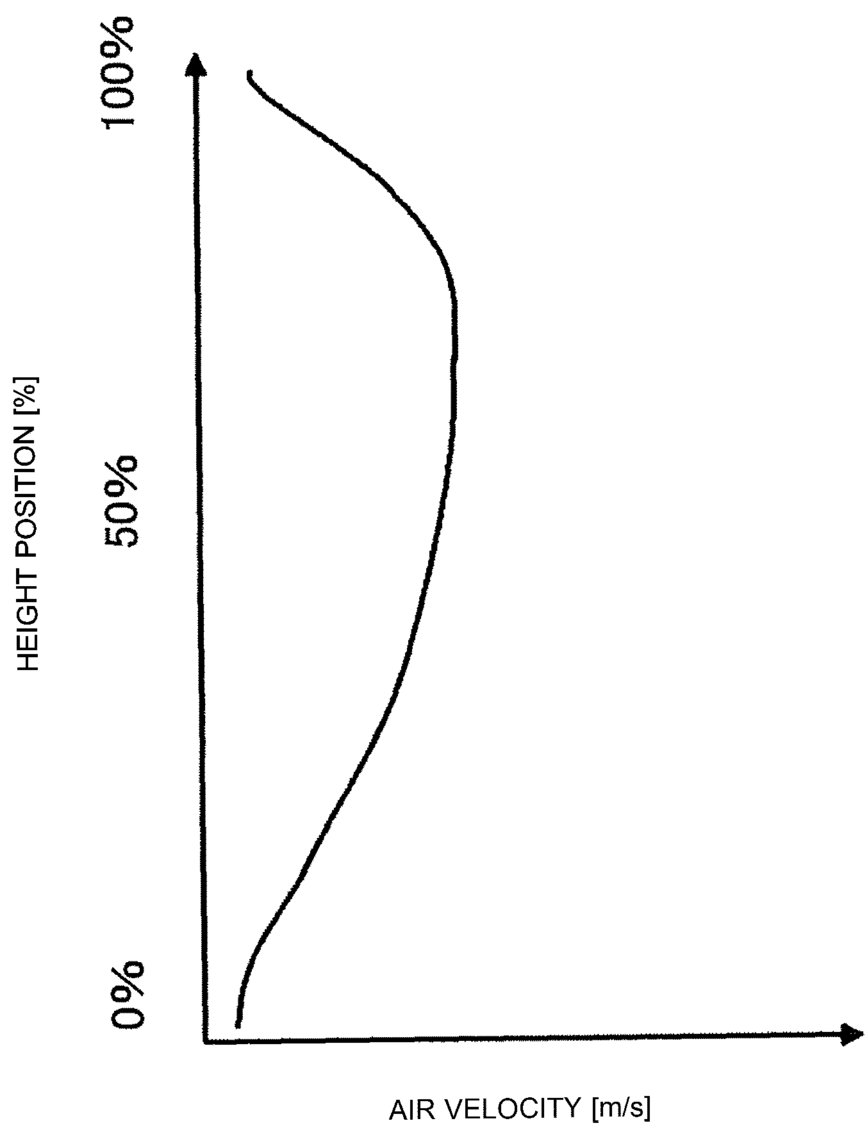


FIG. 21

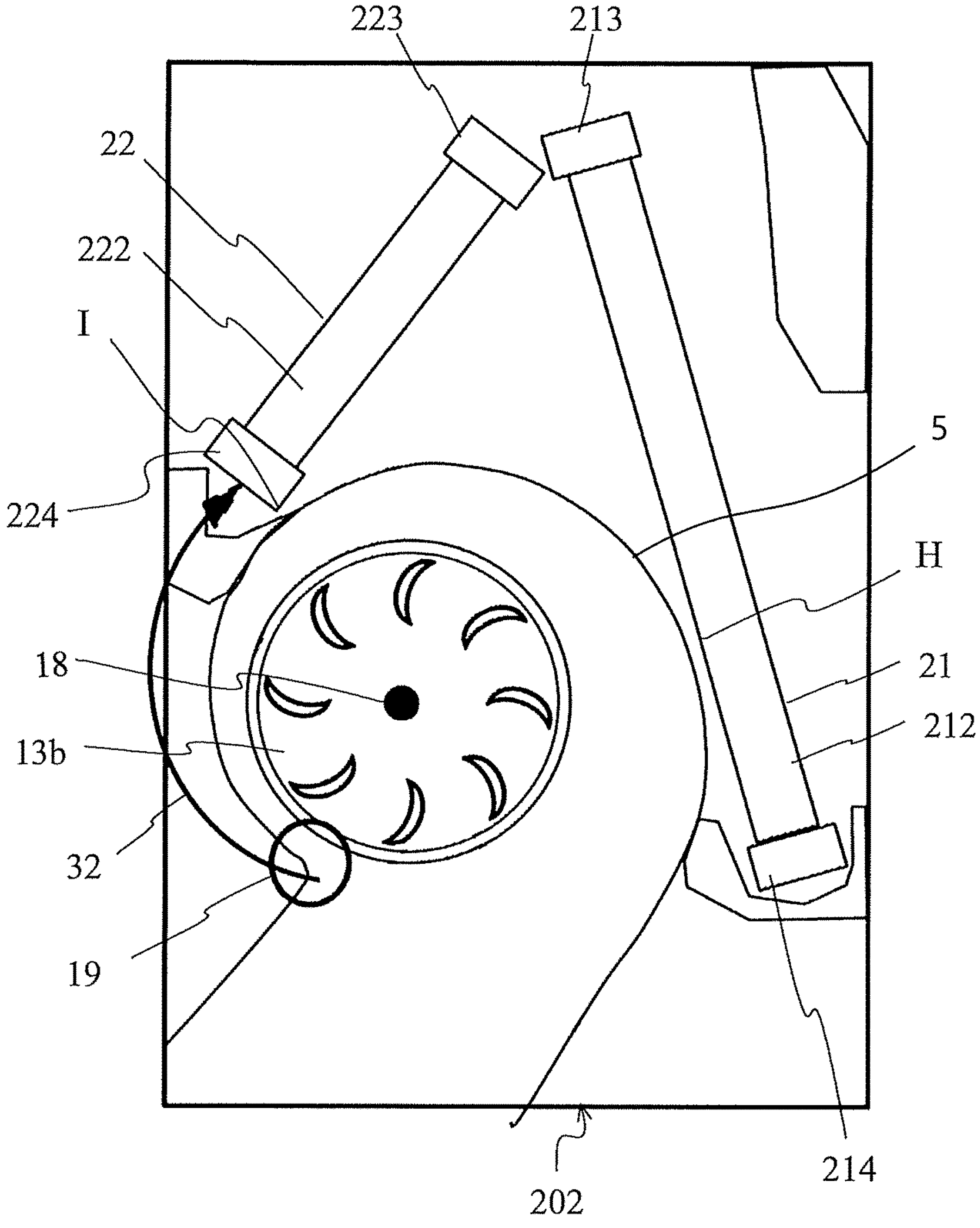
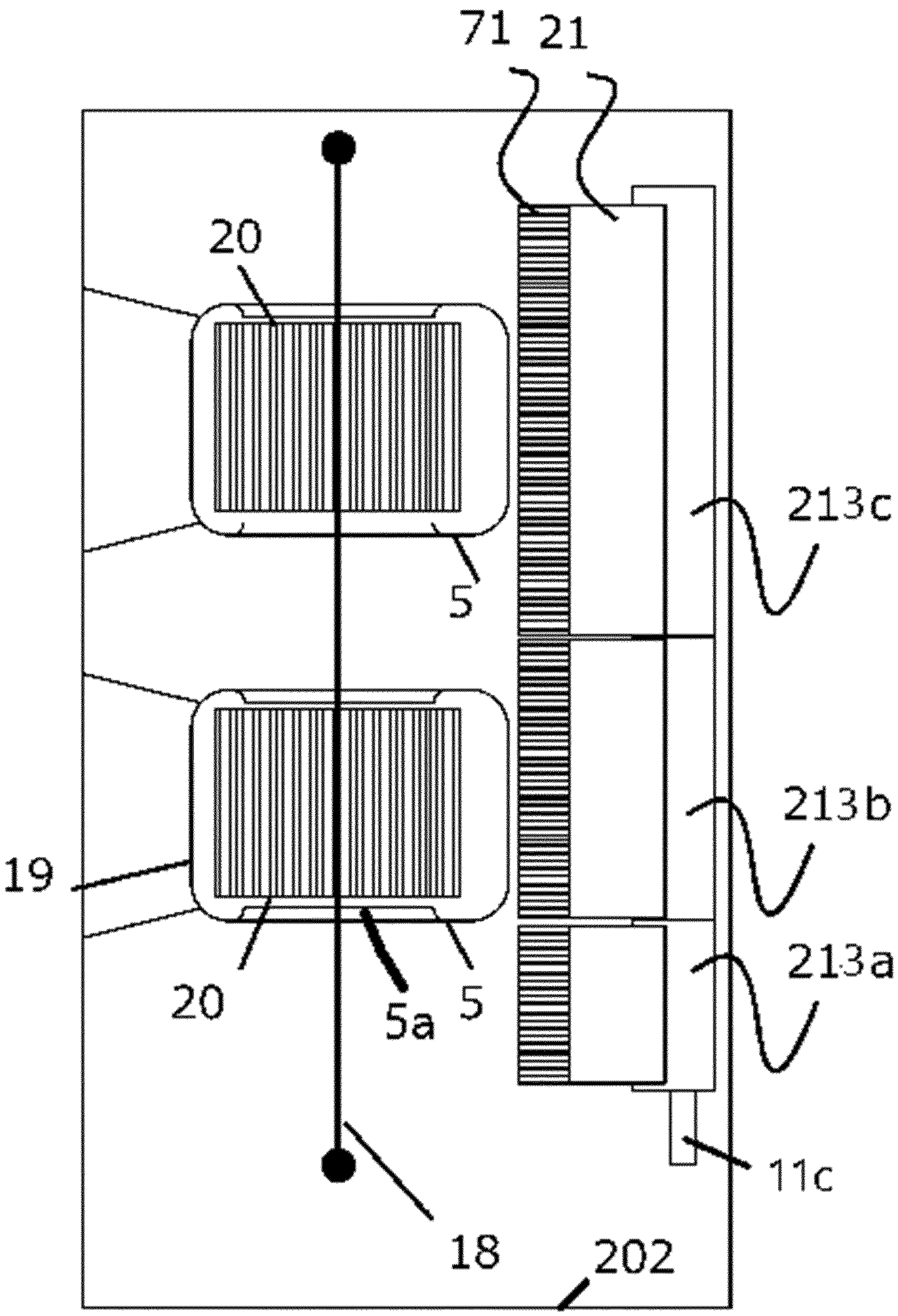


FIG. 22



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/012941

A. CLASSIFICATION OF SUBJECT MATTER
F24F 1/0067(2019.01)i
FI: F24F1/0067

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)
F24F1/0067

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2020-180752 A (PANASONIC IP MAN CORP) 05 November 2020 (2020-11-05) paragraphs [0015]-[0042]	1-14
A	JP 4-268128 A (MATSUSHITA ELECTRIC IND CO LTD) 24 September 1992 (1992-09-24) paragraphs [0013]-[0034]	1-14
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 58596/1988 (Laid-open No. 161106/1989) (DIESEL KIKI CO.) 09 November 1989 (1989-11-09) page 4, line 10 to page 9, line 1	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 2021 (30.04.2021)	25 May 2021 (25.05.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/012941

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2020-180752 A	05 Nov. 2020	(Family: none)	
JP 4-268128 A	24 Sep. 1992	(Family: none)	
JP 1-161106 U1	09 Nov. 1989	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2015230129 A **[0004]**