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(72) Inventors:
• **YATSUYANAGI, Akira**
Tokyo 1008310 (JP)
• **MAEDA, Tsuyoshi**
Tokyo 1008310 (JP)
• **ISHIBASHI, Akira**
Tokyo 1008310 (JP)

(71) Applicant: **MITSUBISHI ELECTRIC CORPORATION**
Chiyoda-ku
Tokyo 100-8310 (JP)

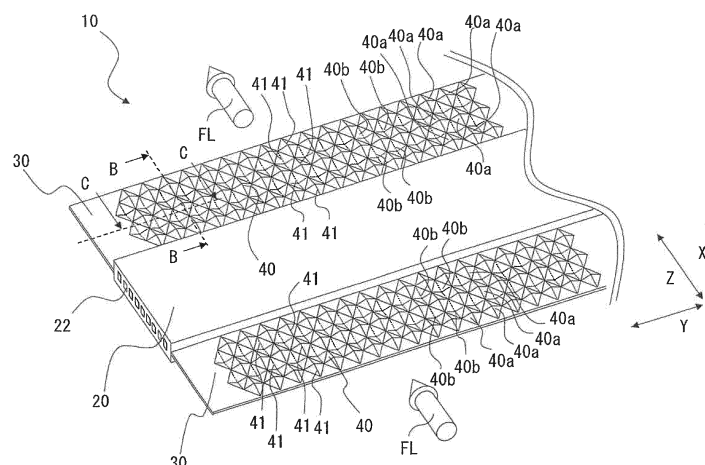
(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) **HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE**

(57) A heat exchanger includes a plurality of heat exchange modules arranged and spaced apart from each other in a first direction, and a header connected to end portions of the plurality of heat exchange modules, the end portions being located at ends of the plurality of heat exchange modules in a second direction crossing perpendicularly to the first direction. The plurality of heat exchange modules each include a heat transfer tube ex-

tending in the second direction, and a fin extending from an edge portion of the heat transfer tube in a third direction crossing perpendicularly to a plane parallel to the first direction and the second direction. The fin includes on its surface a plurality of convex parts each protruding in the first direction. The plurality of convex parts are each provided to define a surface inclined relative to the second direction and the third direction.

FIG. 5



Description

Technical Field

[0001] The present disclosure relates to a heat exchanger, and a refrigeration cycle apparatus including the heat exchanger. More specifically, the present disclosure relates to the structure of a fin connected to a heat transfer tube.

Background Art

[0002] Heat exchangers aiming at achieving balance between their heat transfer performance in dry and wet conditions, and defrost capacity are known in the art. Such a heat exchanger is designed to have heat exchange modules each having a fin provided to an end portion of each heat transfer tube in the direction of airflow through the heat transfer tube. The heat exchange modules are arranged and spaced apart from each other (see Patent Literature 1, for example).

[0003] The above-mentioned heat exchanger is disposed with the direction of tube axis aligned with the direction of gravity. This ensures that no resistance is present to impede falling of condensed or defrosted water, which allows for fast drainage. That is, the above-mentioned heat exchanger allows for reduced liquid film thickness in wet conditions, and fast discharge of defrosted water in defrost operation. The above-mentioned heat exchanger can be improved in heat transfer performance by reducing the diameter of the heat transfer tubes for high-density placement of heat exchange modules, or by employing a multi-port internal structure for increased contact area between refrigerant and the heat transfer tubes. Therefore, the above-mentioned heat exchanger makes it possible to achieve balance between heat transfer performance in dry and wet conditions, and defrost capacity.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2008-202896

Summary of Invention

Technical Problem

[0005] The above-mentioned related-art heat exchanger, however, has a problem described below. That is, in the direction of airflow through the heat exchanger, the fin located downstream in the airflow is disposed to overlies a dead water region generated downstream of the heat transfer tubes. This results in reduced flow velocity of air near the surface of the fin, which leads to reduced coefficient of heat transfer between the fin and

air.

[0006] The present disclosure aims to address the above-mentioned problem, and it is an object of the present disclosure to provide a heat exchanger and a refrigeration cycle apparatus that allow for improved coefficient of heat transfer between the fin and air. Solution to Problem

[0007] A heat exchanger according to an embodiment of the present disclosure includes a plurality of heat exchange modules arranged and spaced apart from each other in a first direction, and a header connected to end portions of the plurality of heat exchange modules, the end portions being located at ends of the plurality of heat exchange modules in a second direction crossing perpendicularly to the first direction. The plurality of heat exchange modules each include a heat transfer tube extending in the second direction, and a fin extending from an edge portion of the heat transfer tube in a third direction crossing perpendicularly to a plane parallel to the first direction and the second direction. The fin includes on its surface a plurality of convex parts each protruding in the first direction. The plurality of convex parts are each provided to define a surface inclined relative to the second direction and the third direction.

[0008] A refrigeration cycle apparatus according to an embodiment of the present disclosure includes the heat exchanger according to an embodiment of the present disclosure.

Advantageous Effects of Invention

[0009] According to an embodiment of the present disclosure, the convex parts are each provided to define a surface inclined relative to the second direction and the third direction. In the heat exchanger, as airflow collides with the surface inclined relative to the second direction and the third direction, the airflow is agitated. This ensures that in the heat exchanger, air also flows in to the surface of the fin located downstream of the heat transfer tube, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus including a heat exchanger according to Embodiment 1.

[Fig. 2] Fig. 2 is a schematic perspective view of the heat exchanger according to Embodiment 1.

[Fig. 3] Fig. 3 is a conceptual side view of the heat exchanger according to Embodiment 1.

[Fig. 4] Fig. 4 schematically illustrates a cross-section, taken along a line A-A, of a heat exchange module illustrated in Fig. 3.

[Fig. 5] Fig. 5 is an enlarged view of a heat exchange

module forming the heat exchanger according to Embodiment 1.

[Fig. 6] Fig. 6 schematically illustrates a cross-section, taken along a line B-B, of a fin illustrated in Fig. 5.

[Fig. 7] Fig. 7 schematically illustrates a cross-section, taken along a line C-C, of the fin illustrated in Fig. 5.

[Fig. 8] Fig. 8 is an enlarged view of the fin of the heat exchange module illustrated in Fig. 5.

[Fig. 9] Fig. 9 schematically illustrates a cross-section, taken along a line D-D, of the fin illustrated in Fig. 8.

[Fig. 10] Fig. 10 schematically illustrates a cross-section, taken along a line E-E, of the fin illustrated in Figs. 8 and 9.

[Fig. 11] Fig. 11 is an enlarged view of a heat exchange module according to a modification and forming the heat exchanger according to Embodiment 1.

[Fig. 12] Fig. 12 is an enlarged view of a heat exchange module forming a heat exchanger according to Embodiment 2.

[Fig. 13] Fig. 13 is an enlarged view of a heat exchange module forming a heat exchanger according to Embodiment 3.

[Fig. 14] Fig. 14 is an enlarged view of a heat exchange module forming a heat exchanger according to Embodiment 4.

[Fig. 15] Fig. 15 schematically illustrates a cross-section of a fin of a heat exchange module forming a heat exchanger according to Embodiment 5.

[Fig. 16] Fig. 16 schematically illustrates a cross-section of a fin of a heat exchange module forming a heat exchanger according to Embodiment 6.

[Fig. 17] Fig. 17 schematically illustrates a cross-section of a fin of another exemplary heat exchange module forming the heat exchanger according to Embodiment 6.

[Fig. 18] Fig. 18 schematically illustrates a cross-section of a fin of a heat exchange module forming a heat exchanger according to Embodiment 7.

[Fig. 19] Fig. 19 is an enlarged view of a heat exchange module forming a heat exchanger according to Embodiment 8.

[Fig. 20] Fig. 20 schematically illustrates a cross-section, taken along a line F-F, of a fin illustrated in Fig. 19.

[Fig. 21] Fig. 21 schematically illustrates a cross-section, taken along a line G-G, of the fin illustrated in Fig. 19.

[Fig. 22] Fig. 22 is an enlarged view of a heat exchange module forming a heat exchanger according to Embodiment 9.

[Fig. 23] Fig. 23 schematically illustrates a cross-section, taken along a line H-H, of a fin illustrated in Fig. 22.

[Fig. 24] Fig. 24 schematically illustrates a cross-section, taken along a line I-I, of the fin illustrated in Fig.

22.

Description of Embodiments

5 **[0011]** A heat exchanger 50 according to Embodiment 1 is described below with reference to the drawings or other illustrations. In the drawings below including Fig. 1, the relative dimensions, shapes, and other features of various components may differ from the actuality. In the drawings below, the same reference signs are used to indicate the same or corresponding elements or features throughout the specification. Although terms representing directions (e.g., "upper", "lower", "right", "left", "front", or "rear") are used as appropriate to facilitate understanding of the present disclosure, such terms are for illustrative purposes only and not intended to limit the corresponding apparatus, device, or component to any particular placement or orientation. The relative positions of individual components, the directions of extension of individual components, and the directions of arrangement of individual components described herein basically correspond to those when the heat exchanger 50 is installed in a usable condition.

25 Embodiment 1

[Refrigeration Cycle Apparatus 100]

30 **[0012]** Fig. 1 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus 100 including the heat exchanger 50 according to Embodiment 1. In Fig. 1, dotted arrows represent the direction in which refrigerant flows in a refrigerant circuit 110 during cooling operation, and solid arrows represent the direction in which refrigerant flows in the refrigerant circuit 110 during heating operation. The refrigeration cycle apparatus 100 including the heat exchanger 50 is first described below with reference to Fig. 1. Although an air-conditioning apparatus is described as an example of the refrigeration cycle apparatus 100 in Embodiment 1, the refrigeration cycle apparatus 100 is used for refrigeration purposes or air-conditioning purposes, for example, refrigerators or freezers, vending machines, air-conditioning apparatuses, refrigeration apparatuses, or water heaters. It is to be noted that the illustrated refrigerant circuit 110 is given only by way of example, and that configurations of circuit elements or other features are not limited to the particular details described below with reference to embodiments but can be changed or modified within the technical scope of the embodiments.

35 **[0013]** The refrigeration cycle apparatus 100 includes the refrigerant circuit 110 obtained by connecting the following components in a loop by use of a refrigerant pipe; a compressor 101; a flow switching device 102; an indoor heat exchanger 103; a pressure reducing device 104; and an outdoor heat exchanger 105. The heat exchanger 50 described later is used as at least one of the outdoor heat exchanger 105 and the indoor heat exchanger 103.

The refrigeration cycle apparatus 100 includes an outdoor unit 106, and an indoor unit 107. The outdoor unit 106 accommodates the following components: the compressor 101; the flow switching device 102; the outdoor heat exchanger 105; the pressure reducing device 104; and an outdoor fan 108 configured to supply outside air to the outdoor heat exchanger 105. The indoor unit 107 accommodates the indoor heat exchanger 103, and an indoor fan 109 configured to supply air to the indoor heat exchanger 103. The outdoor unit 106 and the indoor unit 107 are connected to each other via two extension pipes, an extension pipe 111 and an extension pipe 112, which constitute a portion of the refrigerant pipe.

[0014] The compressor 101 is a piece of fluid machinery that compresses and discharges sucked refrigerant. The flow switching device 102 is, for example, a four-way valve. The flow switching device 102 is configured to, under control by a controller (not illustrated), switch the flows of refrigerant between cooling operation and heating operation.

[0015] The indoor heat exchanger 103 is a heat exchanger configured to perform heat exchange between refrigerant flowing inside the indoor heat exchanger 103, and indoor air supplied by the indoor fan 109. The indoor heat exchanger 103 functions as a condenser during heating operation, and functions as an evaporator during cooling operation.

[0016] The pressure reducing device 104 is, for example, an expansion valve, and configured to reduce the pressure of refrigerant. An example of the pressure reducing device 104 to be used may be an electronic expansion valve whose opening degree can be adjusted through control by the controller.

[0017] The outdoor heat exchanger 105 is a heat exchanger configured to perform heat exchange between refrigerant flowing inside the outdoor heat exchanger 105, and air supplied by the outdoor fan 108. The outdoor heat exchanger 105 functions as an evaporator during heating operation, and functions as a condenser during cooling operation.

[Operation of Refrigeration Cycle Apparatus]

[0018] Reference is now made to Fig. 1 to describe an example of how the refrigeration cycle apparatus 100 operates. During heating operation of the refrigeration cycle apparatus 100, high-pressure and high-temperature refrigerant in a gaseous state discharged from the compressor 101 flows into the indoor heat exchanger 103 via the flow switching device 102. In the indoor heat exchanger 103, the refrigerant condenses in heat exchange with air supplied by the indoor fan 109. The condensed refrigerant changes into a high-pressure liquid state, and then leaves the indoor heat exchanger 103. The resulting refrigerant is turned into a low-pressure, two-phase gas-liquid state by the pressure reducing device 104. The low-pressure refrigerant in the two-phase gas-liquid state flows into the outdoor heat exchanger

105, where the refrigerant evaporates in heat exchange with air supplied by the outdoor fan 108. The evaporated refrigerant changes into a low-pressure gaseous state before being sucked into the compressor 101.

[0019] During cooling operation of the refrigeration cycle apparatus 100, refrigerant flows in the refrigerant circuit 110 in a direction opposite to that during heating operation. That is, during cooling operation of the refrigeration cycle apparatus 100, high-pressure and high-temperature refrigerant in a gaseous state discharged from the compressor 101 flows into the outdoor heat exchanger 105 via the flow switching device 102. In the outdoor heat exchanger 105, the refrigerant condenses in heat exchange with air supplied by the outdoor fan 108. The condensed refrigerant changes into a high-pressure liquid state, and then leaves the outdoor heat exchanger 105. The resulting refrigerant is turned into a low-pressure, two-phase gas-liquid state by the pressure reducing device 104. The low-pressure refrigerant in the two-phase gas-liquid state flows into the indoor heat exchanger 103, where the refrigerant evaporates in heat exchange with air supplied by the indoor fan 109. The evaporated refrigerant changes into a low-pressure gaseous state before being sucked into the compressor 101.

[Heat Exchanger 50]

[0020] Fig. 2 is a schematic perspective view of the heat exchanger 50 according to Embodiment 1. Fig. 3 is a conceptual side view of the heat exchanger 50 according to Embodiment 1. Reference is now made to Figs. 2 and 3 to describe the heat exchanger 50 according to Embodiment 1. In the drawings, the X-axis direction represents a first direction, the Y-axis direction represents a second direction, and the Z-axis direction represents a third direction.

[0021] As illustrated in Fig. 3, the heat exchanger 50 includes a plurality of headers 70, and a plurality of heat exchange modules 10 connected between the headers 70.

(Header 70)

[0022] Each header 70 is connected to end portions of the heat exchange modules 10 in a direction in which the heat exchange modules 10 extend. The header 70 is provided to extend in a direction in which the heat exchange modules 10 are arranged. In the heat exchanger 50, the header 70 functions as a fluid distribution mechanism that allows refrigerant entering the heat exchanger 50 to be distributed to the heat exchange modules 10. In the heat exchanger 50, the header 70 also functions as a fluid combining mechanism that allows separate streams of refrigerant leaving the heat exchange modules 10 to combine before leaving the heat exchanger 50.

[0023] The header 70 has a first header 71, and a second header 72. One of the first header 71 and the second header 72 functions as a fluid distribution mechanism,

and the other functions as a fluid combining mechanism. The first header 71 is connected to one end of each of the heat exchange modules 10 in the direction in which the heat exchange module 10 extends. The second header 72 is connected to the other end of each of the heat exchange modules 10 in the direction in which the heat exchange module 10 extends. That is, the first header 71 and the second header 72 are mounted to opposite ends of each of the heat exchange modules 10 in the direction in which the heat exchange module 10 extends. That is, the header 70 is connected to end portions of the heat exchange modules 10, the end portions being located at ends of the heat exchange modules 10 in the second direction (Y-axis direction) crossing perpendicularly to the first direction (X-axis direction). More specifically, the first header 71 and the second header 72 are mounted to opposite ends of heat transfer tubes 20 forming the heat exchange modules 10 in a direction in which the heat transfer tubes 20 extend. The first header 71 and the second header 72 are connected to the heat transfer tubes 20 of the heat exchange modules 10 in such a way that allows communication between the interior of the header 70 and the interior of the passage of each heat transfer tube 20.

[0024] The header 70 in Figs. 2 and 3 is formed in the shape of a cuboid whose longitudinal direction aligns with the direction of arrangement of the heat exchange modules 10. It is to be noted, however, that the header 70 may not necessarily have the shape of a cuboid but may have another shape, for example, a circular cylinder.

[0025] The first header 71 has an inlet (not illustrated) through which refrigerant enters the first header 71, or has an outlet (not illustrated) through which refrigerant leaves the first header 71. Likewise, the second header 72 has an inlet (not illustrated) through which refrigerant enters the second header 72, or has an outlet (not illustrated) through which refrigerant leaves the second header 72.

(Heat Exchange Module 10)

[0026] Fig. 4 schematically illustrates a cross-section, taken along a line A-A, of each heat exchange module 10 illustrated in Fig. 3. The heat exchange module 10 allows heat to be exchanged between air flowing along the heat exchange module 10 and refrigerant flowing within the heat exchange module 10. The heat exchange modules 10 are arranged and spaced apart from each other in the first direction (X-axis direction). The heat exchange modules 10 are disposed with a predetermined spacing P from each other in the longitudinal direction (X-axis direction) of the header 70. Each heat exchange module 10 has the heat transfer tube 20 extending in the second direction (Y-axis direction). The heat exchange module 10 includes a fin 30. The fin 30 extends from a first edge portion 20a and a second edge portion 20b of the heat transfer tube 20 in the third direction (Z-axis direction) crossing perpendicularly to a plane parallel to

the first direction (X-axis direction) and the second direction (Y-axis direction).

(Heat Transfer Tube 20)

[0027] Each of the heat transfer tubes 20 allows refrigerant to pass therethrough. Each of the heat transfer tubes 20 extends between the first header 71 and the second header 72. The heat transfer tubes 20 are spaced apart from each other, and arranged in the axial direction of the header 70 in which the header 70 extends. The heat transfer tubes 20 are disposed facing each other. A gap through which air passes is defined between each two adjacent heat transfer tubes 20.

[0028] In the heat exchanger 50, the first direction in which the heat transfer tubes 20 are arranged is a horizontal direction. It is to be noted, however, that the first direction in which the heat transfer tubes 20 are arranged may not necessarily be a horizontal direction. Alternatively, the first direction may be a vertical direction, or may be a direction inclined relative to the vertical direction. Likewise, in the heat exchanger 50, the direction in which the heat transfer tubes 20 extend is a vertical direction. It is to be noted, however, that the direction in which the heat transfer tubes 20 extend may not necessarily be a vertical direction but may be a horizontal direction or may be a direction inclined relative to the vertical direction.

[0029] Each two adjacent heat transfer tubes 20 are not connected to each other by a heat-transfer promoting component. The heat-transfer promoting component is, for example, a plate fin or a corrugated fin.

[0030] If the heat exchanger 50 functions as an evaporator for the refrigeration cycle apparatus 100, refrigerant flows within each of the heat transfer tubes 20 from one end to the other end of the heat transfer tube 20 in a direction in which the heat transfer tube 20 extends. If the heat exchanger 50 functions as a condenser for the refrigeration cycle apparatus 100, refrigerant flows within each of the heat transfer tubes 20 from the other end to the one end of the heat transfer tube 20 in the direction in which the heat transfer tube 20 extends.

[0031] As illustrated in Fig. 4, the heat transfer tube 20 is a flattened tube having a rectangular shape in cross-section. The heat transfer tube 20 is not limited to any particular shape. For example, the heat transfer tube 20 may be a flattened tube having a cross-sectional shape that is flattened in one direction, such as an oval shape. The heat transfer tube 20 has a pair of edge portions, and a pair of flat surfaces. The pair of edge portions include the first edge portion 20a and the second edge portion 20b. The pair of flat surfaces includes a flat surface 20c and a flat surface 20d. In the cross-sectional view in Fig. 6, the first edge portion 20a is provided to define a planar surface between one end portion of the flat surface 20c and one end portion of the flat surface 20d. In the above-mentioned cross-sectional view, the second edge portion 20b is provided to define a planar

surface between the other end portion of the flat surface 20c and the other end portion of the flat surface 20d. The first edge portion 20a and the second edge portion 20b may not necessarily have the above-mentioned shape. Alternatively, for example, the first edge portion 20a and the second edge portion 20b may be provided to be outwardly convex between an end portion of the flat surface 20c and an end portion of the flat surface 20d.

[0032] The first edge portion 20a is an edge portion located upstream, that is, near the front edge in the flow of air passing through the heat exchanger 50. The second edge portion 20b is an edge portion located downstream, that is, near the rear edge in the flow of air passing through the heat exchanger 50. In the following description, a direction perpendicular to the direction of extension of the heat transfer tube 20 and along the flat surface 20c and the flat surface 20d is sometimes referred to as long-axis direction of the heat transfer tube 20. In Fig. 4, the long-axis direction of the heat transfer tube 20 is the top-bottom direction, and the short-axis direction of the heat transfer tube 20 is the left-right direction. The long-axis direction of the heat transfer tube 20 corresponds to the third direction.

[0033] The heat transfer tube 20 includes a plurality of refrigerant passages 22 arranged in the long-axis direction between the first edge portion 20a and the second edge portion 20b. The heat transfer tube 20 is a flattened multi-port tube with the refrigerant passages 22 arranged in the direction of flow of air and through which refrigerant passes. Each of the refrigerant passages 22 extends in parallel to the second direction in which the heat transfer tube 20 extends. Adjacent refrigerant passages 22 are separated by partition walls 23, each of which extends continuously to opposite ends of the heat transfer tube 20 in the direction in which the heat transfer tube 20 extends. The number and cross-sectional shape of the refrigerant passages 22 are not limited to those of the depicted embodiment. For example, the refrigerant passages 22 may be formed in various shapes such as a circle or a triangle. The number of refrigerant passages 22 to be provided may be one or more.

(Fin 30)

[0034] The fin 30 protrudes from an end portion of the heat transfer tube 20 in the long-axis direction of the heat transfer tube 20. The fin 30 is a plate-like part disposed to protrude from the first edge portion 20a and the second edge portion 20b and extend in the long-axis direction of each of the heat transfer tubes 20. Although the fin 30 extends in the long-axis direction of the heat transfer tube 20 in the present example, this is not intended to be limiting. For example, the fin 30 may be inclined relative to the long-axis direction at a predetermined angle in the direction of arrangement of the heat transfer tubes 20. The fin 30 may be formed as a component joined to the heat transfer tube 20, or may be formed as a component integrated with the heat transfer tube 20. As described

above, each two adjacent heat transfer tubes 20 are not connected to each other by a heat-transfer promoting component. Accordingly, each one of the heat transfer tubes 20 is not connected to the adjacent one of the heat transfer tubes 20 via the fin 30.

[0035] Fig. 5 is an enlarged view of the heat exchange module 10 forming the heat exchanger 50 according to Embodiment 1. Arrows in Fig. 5 represent airflow FL. Fig. 5 is a partial perspective view of the heat exchange module 10, and thus a portion of the heat exchange module 10 is not illustrated in Fig. 5. Reference is now made to Fig. 5 to describe the configuration of the fin 30 in more detail. The fin 30 includes on its surface a plurality of convex parts 40 each protruding in the first direction (X-axis direction). Each of the convex parts 40 is provided to protrude in the shape of a quadrangular pyramid. The shape of the convex part 40 is not limited to a quadrangular pyramid. For example, the convex part 40 may be formed in the shape of a hemisphere. The convex part 40 is formed such that one side of the convex part 40 in the first direction (X-axis direction) protrudes, and the other side is recessed. The convex parts 40 are arranged in the second direction (Y-axis direction), and are arranged in the third direction (Z-axis direction). The convex parts 40 have edges 41 that extend continuously in the third direction.

[0036] The convex parts 40 include, in the first direction (X-axis direction), first convex parts 40a that protrude from one surface of each convex part 40, and second convex parts 40b that protrude from the other surface of each convex part 40. The first convex parts 40a are arranged in the second direction (Y-axis direction), and are arranged in the third direction (Z-axis direction). Likewise, the second convex parts 40b are arranged in the second direction (Y-axis direction), and are arranged in the third direction (Z-axis direction). The first convex parts 40a are formed with the edges 41 extending continuously in the third direction (Z-axis direction). The second convex parts 40b are formed with the edges 41 extending continuously in the third direction (Z-axis direction). The first convex parts 40a and the second convex parts 40b are formed alternately in a direction inclined relative to the second direction (Y-axis direction) and to the third direction (Z-axis direction).

[0037] Fig. 6 schematically illustrates a cross-section, taken along a line B-B, of the fin 30 illustrated in Fig. 5. The B-B cross-section is a cross-section of the fin 30 that is taken in the third direction (Z-axis direction) and viewed in the second direction (Y-axis direction). Fig. 6 is a partial cross-sectional view of the heat exchange module 10, and thus a portion of the heat exchange module 10 is not illustrated in Fig. 6. As illustrated in Fig. 6, the first convex parts 40a of the fin 30 are each provided to define an inclined surface 42 having an inclination angle α relative to the third direction (Z-axis direction). The inclined surface 42 is a surface located on the protruding side of each convex part 40, and is a slope facing upstream.

[0038] Fig. 7 schematically illustrates a cross-section,

taken along a line C-C, of the fin 30 illustrated in Fig. 5. The C-C cross-section is a cross-section of the fin 30 that is taken in the second direction (Y-axis direction) and viewed in the third direction (Z-axis direction). Fig. 7 is a partial cross-sectional view of the heat exchange module 10, and thus a portion of the heat exchange module 10 is not illustrated in Fig. 7. As illustrated in Fig. 7, the first convex parts 40a of the fin 30 are each provided to define an inclined surface 43 having an inclination angle β relative to the second direction (Y-axis direction).

[Exemplary Operation of Heat Exchanger 50]

[0039] Reference is now made to an example of how the heat exchanger 50 according to Embodiment 1 operates when the heat exchanger 50 functions as an evaporator for the refrigeration cycle apparatus 100. When the heat exchanger 50 functions as an evaporator, two-phase gas-liquid refrigerant flows into the heat exchanger 50 after being reduced in pressure by the pressure reducing device 104. At this time, the refrigerant enters the heat exchanger 50 through the first header 71, and is separated into a number of passes equal to the number of the heat transfer tubes 20. Then, as the refrigerant passes through the respective refrigerant passages 22 of the heat transfer tubes 20, the refrigerant absorbs heat and evaporates. The resulting refrigerant leaves the second header 72 and circulates in the refrigerant circuit 110.

[Advantageous Effects of Heat Exchanger 50]

[0040] Fig. 8 is an enlarged view of the fin 30 of the heat exchange module 10 illustrated in Fig. 5. Fig. 9 schematically illustrates a cross-section, taken along a line D-D, of the fin 30 illustrated in Fig. 8. Fig. 10 schematically illustrates a cross-section, taken along a line E-E, of the fin 30 illustrated in Figs. 8 and 9. Arrows in Figs. 8 and 9 represent airflow FL. Figs. 9 and 10 are partial cross-sectional views of a portion of the heat exchange module 10, and thus a portion of the heat exchange module 10 is not illustrated in Figs. 9 and 10. In the heat exchanger 50, the airflow FL passes between the heat exchange modules 10. In the heat exchanger 50, the airflow FL collides with the first convex parts 40a provided to the fin 30 as illustrated in Fig. 8. The airflow FL thus moves while creating vortices, rather than moving in a straight line. More specifically, as the airflow FL collides with the inclined surfaces 42 of the first convex parts 40a depicted in Fig. 6, the airflow FL forms vortices that rotate in the third direction (Z-axis direction) as illustrated in Fig. 9. The airflow FL that has formed vortices creates a high-velocity flow HL that moves toward a depression HA defined between the first convex parts 40a. Further, as the airflow FL collides with the inclined surfaces 43 of the first convex parts 40a depicted in Fig. 7, the airflow FL forms vortices that rotate in the second direction (Y-axis direction) as illustrated in Fig. 10. Therefore, the first convex parts 40a of the fin 30 cause the airflow FL to form

vortices that rotate in the second and third directions to thereby agitate the flow of air.

[0041] As described above, the convex parts 40 are each provided to define a surface inclined relative to the second direction (Y-axis direction) and the third direction (Z-axis direction). In the heat exchanger 50, as airflow collides with the surface inclined relative to the second direction (Y-axis direction) and the third direction (Z-axis direction), the airflow is agitated. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

[0042] The first convex parts 40a are each formed in the shape of a quadrangular pyramid, and the edges 41 of the first convex parts 40a are provided to extend continuously in the third direction (Z-axis direction). This helps to ensure that in the heat exchanger 50, the airflow FL that have formed vortices is allowed, as a whole, to easily move in the third direction (Z-axis direction) along a ridge portion formed by the edges 41.

[0043] The fin 30 includes the convex parts 40 on its surface. This allows the fin 30 to have an increased surface area in comparison to the fin 30 that includes no convex parts 40. As a result, the heat exchanger 50 can be improved in the efficiency of heat exchange between refrigerant and air.

[0044] Fig. 11 is an enlarged view of a heat exchange module 101 forming the heat exchanger 50 according to Embodiment 1. Fig. 11 is a partial perspective view of the heat exchange module 101, and thus a portion of the heat exchange module 101 is not illustrated in Fig. 11. As illustrated in Fig. 11, a heat transfer tube 120 of the heat exchange module 10 may not be a flattened tube as described above but may be a circular tube. The fin 30 is provided to extend in the radial direction of the heat transfer tube 120, which is a circular tube.

Embodiment 2

[0045] Fig. 12 is an enlarged view of a heat exchange module 10A forming the heat exchanger 50 according to Embodiment 2. An arrow in Fig. 12 represents airflow FL. Fig. 13 is a partial perspective view of the heat exchange module 10A, and thus a portion of the heat exchange module 10A is not illustrated in Fig. 13. Components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. The heat exchange module 10A forming the heat exchanger 50 according to Embodiment 2 differs from the heat exchange module 10 forming the heat exchanger 50 according to Embodiment 1 in the configuration of the fin 30. More specifically, convex parts 140 of the heat exchange module 10A differ in configuration from the convex parts 40 of the heat exchange module 10. Reference is now made to Fig. 12 to describe the configuration of the convex parts 140 provided to the fin 30 in

more detail.

[0046] The heat exchange module 10A includes the fin 30 positioned on both sides of the heat transfer tube 20 across the heat transfer tube 20 in the third direction (Z-axis direction). The fin 30 includes on its surface the convex parts 140 each protruding in the first direction (X-axis direction). The convex parts 140 are each formed in a columnar shape that extends along the plane of the fin 30. Although the convex parts 140 depicted in Fig. 12 are formed in the shape of a pentagonal prism, the shape of the convex parts 140 is not limited to this shape. The convex parts 140 may be formed in any columnar shape with its lateral faces extending along the plane of the fin 30. For example, the convex parts 140 may be formed in the shape of a semicircular column.

[0047] The convex parts 140 are arranged in the second direction (Y-axis direction), and are arranged in the third direction (Z-axis direction). Although each fin 30 is depicted as including two convex parts 140 in the third direction (Z-axis direction) in Fig. 12, the number of convex parts 140 to be provided in the third direction (Z-axis direction) is not limited to two but may be one, or three or more. As for the number of points at which the airflow FL starts to develop vortices as described above, the greater the number, the better. Accordingly, the greater the number of convex parts 140 provided in the third direction (Z-axis direction), the more desirable. Likewise, although each fin 30 is depicted as including twelve convex parts 140 in the second direction (Y-axis direction) in Fig. 12, the number of convex parts 140 to be provided in the second direction (Y-axis direction) is not limited to twelve. As for the number of points at which the airflow FL starts to develop vortices as described above, the greater the number, the better. Accordingly, the greater the number of convex parts 140 provided in the second direction (Y-axis direction), the more desirable.

[0048] The direction D1 of length of each convex part 140 is inclined relative to the direction of length of the heat transfer tube 20. In other words, the direction D1 of length of each convex part 140 is inclined relative to the third direction (Z-axis direction). The convex parts 140 each extend lengthwise in the same direction D1. The convex parts 140 are each formed in a columnar shape, inclined relative to the direction of length of the heat transfer tube 20, and provided to define the inclined surface 42 and the inclined surface 43 described above. Although the direction D1 is described above as being the direction of length of each convex part 140, the direction D1 may be a direction in which an edge defined by the top portion of each convex part 140 extends.

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[0049] As described above, the convex parts 140 are each provided to define a surface inclined relative to the third direction (Z-axis direction). In the heat exchanger 50, as airflow collides with the surface inclined relative to the second direction (Y-axis direction) and the third

direction (Z-axis direction), the flow of air is agitated. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

[0050] The fin 30 includes the convex parts 140 on its surface. This allows the fin 30 to have an increased surface area in comparison to the fin 30 that includes no convex parts 140. As a result, the heat exchanger 50 can be improved in the efficiency of heat exchange between refrigerant and air.

Embodiment 3

[0051] Fig. 13 is an enlarged view of a heat exchange module 10B forming the heat exchanger 50 according to Embodiment 3. An open arrow in Fig. 13 represents airflow FL. Fig. 13 is a partial perspective view of the heat exchange module 10B, and thus a portion of the heat exchange module 10B is not illustrated in Fig. 13. Components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. The heat exchange module 10B forming the heat exchanger 50 according to Embodiment 3 differs from the heat exchange module 10A forming the heat exchanger 50 according to Embodiment 2 in the configuration of the fin 30. More specifically, convex parts 240 of the heat exchange module 10B differ in configuration from the convex parts 140 of the heat exchange module 10A. Reference is now made to Fig. 13 to describe the configuration of the convex parts 240 provided to the fin 30 in more detail.

[0052] The heat exchange module 10B includes the fin 30 positioned on both sides of the heat transfer tube 20 across the heat transfer tube 20 in the third direction (Z-axis direction). The fin 30 includes on its surface the convex parts 240 each protruding in the first direction (X-axis direction). The convex parts 240 are each formed in a columnar shape that extends lengthwise along the plane of the fin 30. Although the convex parts 240 depicted in Fig. 13 are formed in the shape of a pentagonal prism, the shape of the convex parts 240 is not limited to this shape. The convex parts 240 may be formed in any columnar shape that extends lengthwise along the plane of the fin 30. For example, the convex parts 240 may be formed in the shape of a semicircular column.

[0053] The convex parts 240 are arranged in the second direction (Y-axis direction), and are arranged in the third direction (Z-axis direction). Although each fin 30 is depicted as including two convex parts 240 in the third direction (Z-axis direction) in Fig. 13, the number of convex parts 240 to be provided in the third direction (Z-axis direction) is not limited to two but may be one, or three or more. As for the number of points at which the airflow FL starts to develop vortices as described above, the greater the number, the better. Accordingly, it is desirable

that the number of convex parts 240 provided in the third direction (Z-axis direction) be large. Likewise, although each fin 30 is depicted as including twelve convex parts 240 in the second direction (Y-axis direction) in Fig. 13, the number of convex parts 240 to be provided in the second direction (Y-axis direction) is not limited to twelve. As for the number of points at which the airflow FL starts to develop vortices as described above, a greater number is preferable. Accordingly, the greater the number of convex parts 240 provided in the second direction (Y-axis direction), the more desirable.

[0054] The fin 30 of the heat exchange module 10B includes a first fin 30a, and a second fin 30b. The first fin 30a is disposed to extend in the third direction (Z-axis direction) from the first edge portion 20a of the heat transfer tube 20. The second fin 30b is disposed to extend in the third direction (Z-axis direction) from the second edge portion 20b. The first fin 30a corresponds to the fin 30 located upstream in the airflow FL relative to the heat transfer tube 20. The second fin 30b corresponds to the fin 30 located downstream in the airflow FL relative to the heat transfer tube 20.

[0055] The direction D1 of length of each convex part 240 provided to the first fin 30a is inclined relative to the direction of length of the heat transfer tube 20. In other words, the direction D1 of length of each convex part 240 is inclined relative to the third direction (Z-axis direction). The convex parts 240 provided to the first fin 30a each extend lengthwise in the same direction D1. The convex parts 240 provided to the first fin 30a are each formed in a columnar shape, inclined relative to the direction of length of the heat transfer tube 20, and provided to define the inclined surface 42 and the inclined surface 43 described above. Although the direction D1 is described above as being the direction of length of each convex part 240, the direction D1 may be a direction in which an edge defined by the top portion of each convex part 240 extends.

[0056] A direction D2 of length of each convex part 240 provided to the second fin 30b is inclined relative to the direction of length of the heat transfer tube 20. In other words, the direction D2 of length of each convex part 240 is inclined relative to the third direction (Z-axis direction). The convex parts 240 provided to the second fin 30b each extend lengthwise in the same direction D2. The convex parts 240 provided to the second fin 30b are each formed in a columnar shape, inclined relative to the direction of length of the heat transfer tube 20, and provided to define the inclined surface 42 and the inclined surface 43 described above. Although the direction D2 is described above as being the direction of length of each convex part 240, the direction D2 may be a direction in which an edge defined by the top portion of each convex part 240 extends.

[0057] With respect to the direction of length of each convex part 240, an end portion of the convex part 240 located near the heat transfer tube 20 is defined as a first end portion 240a, and an end portion of the convex part

240 located opposite to the heat transfer tube 20 is defined as a second end portion 240b. The fin 30 is provided such that the first end portion 240a of each convex part 240 provided to the first fin 30a and the second fin 30b is positioned toward one end portion T1 of the heat transfer tube 20. In the fin 30, the second end portion 240b of each convex part 240 provided to the first fin 30a and the second fin 30b is positioned toward the other end portion T2 of the heat transfer tube 20.

[0058] As illustrated in Fig. 13, the direction D1 of length of each convex part 240 provided to the first fin 30a, and the direction D2 of length of each convex part 240 provided to the second fin 30b are inclined at different angles relative to the third direction (Z-axis direction). That is, the fin 30 is positioned on both sides of the heat transfer tube 20 across the heat transfer tube 20 in the third direction (Z-axis direction). In the fin 30, the direction D1 of length of each convex part 240 provided to the fin 30 positioned on one side of the heat transfer tube 20, and the direction D2 of length of each convex part 240 provided to the fin 30 positioned on the other side of the heat transfer tube 20 have different inclinations from each other relative to the third direction (Z-axis direction).

[0059] In the implementation depicted in Fig. 13, the direction D1 of length of each convex part 240 provided to the first fin 30a, and the direction D2 of length of each convex part 240 provided to the second fin 30b are inclined symmetrically about the heat transfer tube 20. That is, in the heat exchange module 10, the inclination of the direction D1 relative to the third direction (Z-axis direction), and the inclination of the direction D2 relative to the third direction (Z-axis direction) are symmetric about the heat transfer tube 20. It is to be noted, however, that the direction D1 of length of each convex part 240 provided to the first fin 30a, and the direction D2 of length of each convex part 240 provided to the second fin 30b may not necessarily be inclined symmetrically about the heat transfer tube 20.

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[0060] The fin 30 is positioned on both sides of the heat transfer tube 20 across the heat transfer tube 20 in the third direction (Z-axis direction). In the fin 30, the direction D1 of length of each convex part 240 provided to the fin 30 positioned on one side of the heat transfer tube 20, and the direction D2 of length of each convex part 240 provided to the fin 30 positioned on the other side of the heat transfer tube 20 have different inclinations from each other relative to the third direction (Z-axis direction). This ensures that in the heat exchanger 50, the direction in which each convex part 240 is inclined differs between the upstream and downstream sides in the airflow relative to the heat transfer tube 20. This leads to further agitation of the airflow. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved

heat transfer coefficient.

[0061] Further, the fin 30 is provided such that on both sides of the heat transfer tube 20, the direction D1 of length of each convex part 240 provided to the fin 30 positioned on one side of the heat transfer tube 20, and the direction D2 of length of each convex part 240 provided to the fin 30 positioned on the other side of the heat transfer tube 20 are symmetric about the heat transfer tube 20. This ensures that in the heat exchanger 50, the direction in which each convex part 240 is inclined differs between the upstream and downstream sides in the air-flow relative to the heat transfer tube 20. This leads to further agitation of the airflow. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

[0062] The convex parts 240 are each provided to define a surface inclined relative to the third direction (Z-axis direction). In the heat exchanger 50, as airflow collides with the surface inclined relative to the second direction (Y-axis direction) and the third direction (Z-axis direction), the flow of air is agitated. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

[0063] The fin 30 includes the convex parts 240 on its surface. This allows the fin 30 to have an increased surface area in comparison to the fin 30 that includes no convex parts 240. As a result, the heat exchanger 50 can be improved in the efficiency of heat exchange between refrigerant and air.

Embodiment 4

[0064] Fig. 14 is an enlarged view of a heat exchange module 10C forming the heat exchanger 50 according to Embodiment 4. An open arrow in Fig. 14 represents air-flow FL. Fig. 14 is a partial perspective view of the heat exchange module 10C, and thus a portion of the heat exchange module 10C is not illustrated in Fig. 14. Components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. The heat exchange module 10C forming the heat exchanger 50 according to Embodiment 4 differs from the heat exchange module 10A forming the heat exchanger 50 according to Embodiment 2 in the configuration of the fin 30. More specifically, convex parts 340 of the heat exchange module 10C differ in configuration from the convex parts 140 of the heat exchange module 10A. Reference is now made to Fig. 14 to describe the configuration of the convex parts 340 provided to the fin 30 in more detail.

[0065] The heat exchange module 10C includes the fin 30 positioned on both sides of the heat transfer tube 20 across the heat transfer tube 20 in the third direction

(Z-axis direction). The fin 30 includes on its surface the convex parts 340 each protruding in the first direction (X-axis direction). The convex parts 340 are each formed in a columnar shape that extends along the plane of the fin 30. Although the convex parts 340 depicted in Fig. 14 are formed in the shape of a pentagonal prism, the shape of the convex parts 340 is not limited to this shape. The convex parts 340 may be formed in any columnar shape that extends along the plane of the fin 30. For example, the convex parts 340 may be formed in the shape of a semicircular column.

[0066] The convex parts 340 each include a first convex part 341, and a second convex part 342. The first convex part 341 and the second convex part 342 are spaced apart from each other in the second direction (Y-axis direction). With respect to the direction of length of each convex part 340, an end portion of the convex part 340 located near the heat transfer tube 20 is defined as a first end portion 340a, and an end portion of the convex part 340 located opposite to the heat transfer tube 20 is defined as a second end portion 340b.

[0067] The fin 30 is provided such that the first end portion 340a of each first convex part 341 is positioned toward the one end portion T1 of the heat transfer tube 20. Further, the fin 30 is provided such that the second end portion 340b of each first convex part 341 is positioned toward the other end portion T2 of the heat transfer tube 20.

[0068] For the first fin 30a, the direction D1 of length of each first convex part 341 is inclined relative to the direction of length of the heat transfer tube 20. In other words, for the first fin 30a, the direction D1 of length of each first convex part 341 is inclined relative to the third direction (Z-axis direction). For the first fin 30a, the first convex parts 341 provided to the fin 30 each extend lengthwise in the same direction D1. The first convex parts 341 are each formed in a columnar shape, inclined relative to the direction of length of the heat transfer tube 20, and provided to define the inclined surface 42 and the inclined surface 43 described above.

[0069] For the second fin 30b, the direction D2 of length of each first convex part 341 is inclined relative to the direction of length of the heat transfer tube 20. In other words, for the second fin 30b, the direction D2 of length of each first convex part 341 is inclined relative to the third direction (Z-axis direction). For the second fin 30b, the first convex parts 341 provided to the fin 30 each extend lengthwise in the same direction D2.

[0070] The fin 30 is provided such that the first end portion 340a of each second convex part 342 is positioned toward the other end portion T2 of the heat transfer tube 20. Further, the fin 30 is provided such that the second end portion 340b of each second convex part 342 is positioned toward the one end portion T1 of the heat transfer tube 20.

[0071] For the first fin 30a, the direction D2 of length of each second convex part 342 is inclined relative to the direction of length of the heat transfer tube 20. In other

words, for the first fin 30a, the direction D2 of length of each second convex part 342 is inclined relative to the third direction (Z-axis direction). For the first fin 30a, the second convex parts 342 provided to the fin 30 each extend lengthwise in the same direction D2. The second convex parts 342 are each formed in a columnar shape, inclined relative to the direction of length of the heat transfer tube 20, and provided to define the inclined surface 42 and the inclined surface 43 described above.

[0072] For the second fin 30b, the direction D1 of length of each second convex part 342 is inclined relative to the direction of length of the heat transfer tube 20. In other words, for the second fin 30b, the direction D1 of length of each second convex part 342 is inclined relative to the third direction (Z-axis direction). For the second fin 30b, the second convex parts 342 provided to the fin 30 each extend lengthwise in the same direction D1.

[0073] For the convex parts 340, the first convex parts 341 are arranged in the third direction (Z-axis direction). For the convex parts 340, the second convex parts 342 are arranged in the third direction (Z-axis direction). Further, for the convex parts 340, the first convex parts 341 and the second convex parts 342 are disposed alternately in a continuous manner in the second direction (Y-axis direction).

[0074] As illustrated in Fig. 14, the convex parts 340 each include the first convex part 341 and the second convex part 342, which have different inclinations from each other relative to the third direction (Z-axis direction) and are spaced apart from each other in the second direction (Y-axis direction). Due to the combination of the first convex part 341 and the second convex part 342 that have different inclinations, in the second direction (Y-axis direction), the convex parts 340 are formed in the shape of a line that is bent at an angle at predetermined intervals at each of which the line doubles back in the opposite direction. That is, the convex parts 340 are formed in the shape of serrations or corrugations in the second direction (Y-axis direction). As for the number of points at which the airflow FL starts to develop vortices as described above, the greater the number, the better. Accordingly, the greater the number of convex parts 340 provided in the second direction (Y-direction) and the third direction (Z-axis direction), the more desirable.

[Advantageous Effects of Heat Exchanger 50]

[0075] The convex parts 340 each include the first convex part 341 and the second convex part 342. The first convex part 341 and the second convex part 342 have different inclinations from each other relative to the third direction (Z-axis direction), and are spaced apart from each other in the second direction (Y-axis direction). Due to the combination of the first convex part 341 and the second convex part 342, in the second direction (Y-axis direction), the convex parts 340 are formed in the shape of a line that is bent at an angle at predetermined intervals at each of which the line doubles back in the opposite

direction. Consequently, each convex part 340 defines a progressively narrowing wall in the third direction (Z-axis direction), which is the direction of airflow. This facilitates collision between flows of air moving in the third direction (Z-axis direction), which leads to further agitation of airflow. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

[0076] The convex parts 340 are each provided to define a surface inclined relative to the third direction (Z-axis direction). In the heat exchanger 50, as airflow collides with the surface inclined relative to the second direction (Y-axis direction) and the third direction (Z-axis direction), the flow of air is agitated. Consequently, in the heat exchanger 50, air also flows in to the surface of the fin 30 located downstream of the heat transfer tube 20, and the flow velocity of air near the surface increases. This leads to improved heat transfer coefficient.

[0077] The fin 30 includes the convex parts 340 on its surface. This allows the fin 30 to have an increased surface area in comparison to the fin 30 that includes no convex parts 340. As a result, the heat exchanger 50 can be improved in the efficiency of heat exchange between refrigerant and air.

Embodiment 5.

[0078] Fig. 15 schematically illustrates a cross-section of the fin 30 of a heat exchange module 10D forming the heat exchanger 50 according to Embodiment 5. Fig. 15 schematically illustrates a cross-section, taken along the line B-B, of the fin 30 illustrated in Fig. 5. Fig. 15 is a partial cross-sectional view of the heat exchange module 10D, and thus a portion of the heat exchange module 10D is not illustrated in Fig. 15. The depicted convex parts 40 of the fin 30 are illustrative only. As the configuration of each convex part 40 described below, the configuration of one of convex parts 40 to 440, which have been described above or will be described later, is employed. In the following description, components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below.

[0079] The heat exchanger 50 includes the heat exchange module 10D, which includes the heat transfer tube 20 and the fin 30. In the heat exchange module 10D of the heat exchanger 50, the fin 30 has a root portion 31 serving as a base portion connected to the heat transfer tube 20. The root portion 31 is offset toward protruding portions of the convex parts 40 in the first direction (X-axis direction), relative to a middle portion 21 of the thickness of the heat transfer tube 20 in the first direction (X-axis direction).

[Advantageous Effects of Heat Exchanger 50]

[0080] As described above, the root portion 31 of the fin 30 is offset toward protruding portions of the convex parts 40 in the first direction (X-axis direction), relative to the middle portion 21 of the thickness of the heat transfer tube 20 in the first direction (X-axis direction). Thus, as illustrated in Fig. 15, the area of the fin 30 exposed from a dead water region DA increases. This facilitates collision of airflow against the surface of each convex part 40 of the fin 30 in the heat exchange module 10D of the heat exchanger 50. As a result, in the heat exchanger 50, the flow velocity of air near the surface of the fin 30 increases, which leads to improved heat transfer coefficient. The above-mentioned configuration of the heat exchange module 10D of the heat exchanger 50 also ensures that sufficient collision occurs between the airflow and the surface of the fin 30. This helps to reduce the required height of the convex part 40, which leads to improved formability of the convex part 40.

Embodiment 6

[0081] Fig. 16 schematically illustrates a cross-section of the fin 30 of a heat exchange module 10E forming the heat exchanger 50 according to Embodiment 6. Fig. 17 schematically illustrates a cross-section of the fin 30 of another example of the heat exchange module 10E forming the heat exchanger 50 according to Embodiment 6. Each of Figs. 16 and 17 schematically illustrates a cross-section, taken along the line B-B, of the fin 30 illustrated in Fig. 5. Figs. 16 and 17 are partial cross-sectional views of the heat exchange module 10E, and thus a portion of the heat exchange module 10E is not illustrated in Figs. 16 and 17. An open arrow in each of Figs. 16 and 17 represents airflow FL. The depicted convex parts 40 of the fin 30 are illustrative only. As the configuration of each convex part 40 described below, the configuration of one of convex parts 40 to 440, which have been described above or will be described later, is employed. In the following description, components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below.

[0082] The heat exchanger 50 includes the heat exchange module 10E, which includes the heat transfer tube 20 and the fin 30. In the heat exchange module 10E of the heat exchanger 50, at least one of the convex parts 40 has a top portion 45 that is positioned outside the heat transfer tube 20 in the first direction (X-axis direction). The top portion 45 is a portion located at the tip of each convex part 40 in the direction in which the convex part 40 protrudes.

[0083] As described above, the second fin 30b corresponds to the fin 30 located downstream in the airflow FL relative to the heat transfer tube 20. In the heat exchange module 10E of the heat exchanger 50, at least one convex part 40 located downstream of the heat trans-

fer tube 20 has the top portion 45 that is positioned outside the width WT of the heat transfer tube 20 in the first direction (X-axis direction). This facilitates exposure of the convex part 40 to air.

[0084] As illustrated in Fig. 16, in the heat exchange module 10E of the heat exchanger 50, the root portion 31 of the fin 30 may be positioned at the location of the middle portion 21 of the thickness of the heat transfer tube 20 in the first direction (X-axis direction). Alternatively, as illustrated in Fig. 17, the root portion 31 may be offset toward protruding portions of the convex parts 40 in the first direction (X-axis direction), relative to the middle portion 21 of the thickness of the heat transfer tube 20 in the first direction (X-axis direction).

[Advantageous Effects of Heat Exchanger 50]

[0085] In the heat exchange module 10E of the heat exchanger 50, at least one of the convex parts 40 has the top portion 45 that is positioned outside the heat transfer tube 20 in the first direction (X-axis direction). The above-mentioned configuration of the heat exchange module 10E of the heat exchanger 50 facilitates collision of airflow against the second fin 30b located downstream of the heat transfer tube 20. This allows the airflow to develop a stronger vortex flow. As a result, in the heat exchanger 50, air increases in flow velocity near the surface of the fin 30 located downstream in the airflow relative to the heat transfer tube 20. This further improves heat transfer coefficient.

Embodiment 7

[0086] Fig. 18 schematically illustrates a cross-section of the fin 30 of a heat exchange module 10F forming the heat exchanger 50 according to Embodiment 7. Fig. 18 schematically illustrates a cross-section, taken along the line B-B, of the fin 30 illustrated in Fig. 5. Fig. 18 is a partial cross-sectional view of the heat exchange module 10F, and thus a portion of the heat exchange module 10F is not illustrated in Fig. 18. An open arrow in Fig. 18 represents airflow FL. The depicted convex parts 40 of the fin 30 are illustrative only. As the configuration of each convex part 40 described below, the configuration of one of convex parts 40 to 440, which have been described above or will be described later, is employed. In the following description, components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below.

[0087] The heat exchanger 50 includes the heat exchange module 10F, which includes the heat transfer tube 20 and the fin 30. The fin 30 of the heat exchange module 10F of the heat exchanger 50 is positioned on both sides of the heat transfer tube 20 across the heat transfer tube 20 in the third direction (Z-axis direction). The convex parts 40 provided to the fin 30 positioned on one side of the heat transfer tube 20 are all positioned

within the width WT of the heat transfer tube 20 in the first direction (X-axis direction).

[0088] As described above, the first fin 30a corresponds to the fin 30 located upstream in the airflow FL relative to the heat transfer tube 20, and the second fin 30b corresponds to the fin 30 located downstream in the airflow FL relative to the heat transfer tube 20. In each of the heat exchange modules 10F, the convex parts 40 provided to the first fin 30a positioned on the other side of the heat transfer tube 20 from the second fin 30b are positioned within the width WT of the heat transfer tube 20 in the first direction (X-axis direction). In the heat exchange module 10F, the convex parts 40 located upstream of the heat transfer tube 20 each have the top portion 45 that is positioned inside the width WT of the heat transfer tube 20 in the first direction (X-axis direction). This helps to ensure less exposure of the convex part 40 to air relative to the heat transfer tube.

[Advantageous Effects of Heat Exchanger 50]

[0089] In each of the heat exchange modules 10F, the convex parts 40 provided to the first fin 30a disposed downstream in the airflow FL relative to the heat transfer tube 20 are all positioned within the width WT of the heat transfer tube 20 in the first direction (X-axis direction). This helps to ensure that in each of the heat exchange modules 10F of the heat exchanger 50, agitation of air upstream of the heat transfer tube 20 occurs in areas near the heat exchange module 10F. As a result, in each of the heat exchange modules 10F of the heat exchanger 50, airflow is easily directed to the heat transfer tube 20 or to the second fin 30b located downstream of the heat transfer tube 20. This further improves heat transfer coefficient.

Embodiment 8

[0090] Fig. 19 is an enlarged view of a heat exchange module 10G forming the heat exchanger 50 according to Embodiment 8. Fig. 20 schematically illustrates a cross-section, taken along a line F-F, of the fin 30 illustrated in Fig. 19. Fig. 21 schematically illustrates a cross-section, taken along a line G-G, of the fin 30 illustrated in Fig. 19. Fig. 19 is a partial perspective view of the heat exchange module 10G, and thus a portion of the heat exchange module 10G is not illustrated in Fig. 19. Figs. 20 and 21 are partial cross-sectional views of the heat exchange module 10G, and thus a portion of the heat exchange module 10G is not illustrated in Figs. 20 and 21. Open arrows in Figs. 19 to 21 represent airflow FL. The depicted convex parts 40 of the fin 30 are illustrative only. As the configuration of each convex part 40 described below, the configuration of one of convex parts 40 to 440, which have been described above or will be described later, is employed. In the following description, components identical in function and operation to those described above with reference to Embodiment 1 are

designated by the same reference signs and not described in further detail below.

[0091] The heat exchanger 50 includes the heat exchange module 10G, which includes the heat transfer tube 20 and the fin 30. The heat exchange module 10G of the heat exchanger 50 includes a flat portion 36. The flat portion 36 is obtained by forming the fin 30 to have a flat surface in both end portions of the fin 30 that extend in the second direction (Y-axis direction) or the third direction (Z-axis direction). More specifically, the heat exchange module 10G of the heat exchanger 50 includes a first flat portion 35 obtained by forming the fin 30 to have a flat surface in both end portions of the fin 30 that extend in the second direction (Y-axis direction). The first flat portion 35 is provided in an edge portion of the fin 30, and extends in the second direction (Y-axis direction). Alternatively, the heat exchange module 10G of the heat exchanger 50 includes a second flat portion 37 obtained by forming the fin 30 to have a flat surface in both end portions of the fin 30 that extend in the third direction (Y-axis direction). The second flat portion 37 is provided in an edge portion of the fin 30, and extends in the third direction (Z-axis direction).

[Advantageous Effects of Heat Exchanger 50]

[0092] The heat exchange module 10G of the heat exchanger 50 includes the flat portion 36. The flat portion 36 is obtained by forming the fin 30 to have a flat surface in both end portions of the fin 30 that extend in the second direction (Y-axis direction) or the third direction (Z-axis direction). The presence of the flat portion 36 in the heat exchange module 10G of the heat exchanger 50 ensures that the heat exchange module 10G be provided with a hold-down portion that serves as a reference plane in forming irregularities corresponding to the convex parts 40. The presence of the flat portion 36 as a hold-down portion in the heat exchange module 10G of the heat exchanger 50 helps to prevent or reduce wear of the forming machine, which leads to reduced manufacturing cost.

Embodiment 9

[0093] Fig. 22 is an enlarged view of a heat exchange module 10H forming the heat exchanger 50 according to Embodiment 9. Fig. 22 is a partial perspective view of the heat exchange module 10H, and thus a portion of the heat exchange module 10H is not illustrated in Fig. 22. Open arrows in Fig. 22 represent airflow FL. In the following description, components identical in function and operation to those described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below.

[0094] The fin 30 includes on its surface a plurality of convex parts 440 each protruding in the first direction (X-axis direction). Each convex part 440 has the shape of a triangular pyramid, and protrudes to define lateral faces 441 of the triangular pyramid. The convex part 440 is

formed with the lateral faces 441 of the triangular pyramid facing upstream in the airflow FL. That is, the convex part 440 is formed such that its portion near an apex 442 is located upstream in the airflow. The convex part 440 is formed such that its edge 443 located near the tip in the first direction (X-axis direction) is aligned with the third direction (Z-axis direction). The shape of the convex part 440 described above is only an example. The shape of the convex part 440 is not limited to the above-mentioned shape. For example, the convex part 440 may be formed in other shapes such as another pyramid, a circular cone, or a hemisphere.

[0095] The convex parts 440 are arranged in the second direction (Y-axis direction). The convex parts 440 arranged in the second direction (Y-axis direction) are arranged in rows in the third direction (Z-axis direction). In this case, odd and even rows are offset from each other in the second direction (Y-axis direction). Of each two rows of the convex parts 440 in the third direction (Z-axis direction), each convex part 440 in the back row is positioned between adjacent convex parts 440 in the front row.

[0096] Fig. 23 schematically illustrates a cross-section, taken along a line H-H, of the fin 30 illustrated in Fig. 22. The H-H cross-section is a cross-section of the fin 30 that is taken in the third direction (Z-axis direction) and viewed in the second direction (Y-axis direction). Fig. 23 is a partial cross-sectional view of the heat exchange module 10H, and thus a portion of the heat exchange module 10H is not illustrated in Fig. 23. As illustrated in Fig. 23, the convex parts 440 of the fin 30 are each provided to define an inclined surface 46 having an inclination angle α relative to the third direction (Z-axis direction). The inclined surface 46 is a surface located on the protruding side of each convex part 440, and is a slope facing upstream in the direction of the airflow FL. That is, the inclined surface 46 is a surface located on the protruding side of each convex part 440, and is a surface positioned not near the distal end of the fin 30 but near the root portion 31 where the heat transfer tube 20 is disposed.

[0097] Fig. 24 schematically illustrates a cross-section, taken along a line I-I, of the fin 30 illustrated in Fig. 22. The I-I cross-section is a cross-section of the fin 30 that is taken in the second direction (Y-axis direction) and viewed in the third direction (Z-axis direction). Fig. 24 is a partial cross-sectional view of the heat exchange module 10H, and thus a portion of the heat exchange module 10H is not illustrated in Fig. 24. As illustrated in Fig. 24, the convex parts 440 of the fin 30 are each provided to define an inclined surface 47 having an inclination angle β relative to the second direction (Y-axis direction).

[0098] As described above, each of the convex parts 440 is provided to have an inclination angle α that is less than an inclination angle β , where the inclination angle α is defined as an angle formed by the convex part 440 with the third direction (Z-axis direction), and the inclination angle β is defined as an angle formed by the convex part 440 with the second direction (Y-axis direction). That

is, each of the convex parts 440 is provided to have the inclination angle α that is less than the inclination angle β .

[Advantageous Effects of Heat Exchanger 50]

[0099] The convex parts 440 are each provided to have the inclination angle α that is less than the inclination angle β . The above-mentioned configuration of the heat exchange module 10H of the heat exchanger 50 helps to reduce the deflection angle of airflow in the third direction (Z-axis direction) while allowing the convex parts 440 to be formed at high density in the second direction (Y-axis direction). This allows the heat exchanger 50 to have an improved balance between heat transfer performance and resistance to airflow, which leads to enhanced heat exchanger performance.

[Operational Effects of Refrigeration Cycle Apparatus 100]

[0100] The refrigeration cycle apparatus 100 described above includes the heat exchanger according to any one of Embodiments 1 to 3. Accordingly, the refrigeration cycle apparatus 100 provides effects similar to those of Embodiment 1 or 2. Therefore, the refrigeration cycle apparatus 100 is equipped with a heat exchanger with high heat transfer performance, which leads to improved energy efficiency of the air-conditioning system.

[0101] Embodiments 1 to 9 mentioned above can be practiced in combination with each other. The configurations described above with reference to the embodiments are intended to be illustrative only. These configurations can be combined with other known techniques, or can be partially omitted or changed without departing from the scope of the present disclosure.

Reference Signs List

[0102] 10: heat exchange module, 10A: heat exchange module, 10B: heat exchange module, 10C: heat exchange module, 10D: heat exchange module, 10E: heat exchange module, 10F: heat exchange module, 10G: heat exchange module, 10H: heat exchange module, 10I: heat exchange module, 20: heat transfer tube, 20a: first edge portion, 20b: second edge portion, 20c: flat surface, 20d: flat surface, 21: middle portion, 22: refrigerant passage, 23: partition wall, 30: fin, 30a: first fin, 30b: second fin, 31: root portion, 35: first flat portion, 36: flat portion, 37: second flat portion, 40: convex part, 40a: first convex part, 40b: second convex part, 41: edge, 42: inclined surface, 43: inclined surface, 45: top portion, 46: inclined surface, 47: inclined surface, 50: heat exchanger, 70: header, 71: first header, 72: second header, 100: refrigeration cycle apparatus, 101: compressor, 102: flow switching device, 103: indoor heat exchanger, 104: pressure reducing device, 105: outdoor heat exchanger, 106: outdoor unit, 107: indoor unit, 108: outdoor fan, 109: indoor fan, 110: refrigerant circuit, 111: extension pipe,

112: extension pipe, 120: heat transfer tube, 140: convex part, 240: convex part, 240a: first end portion, 240b: second end portion, 340: convex part, 340a: first end portion, 340b: second end portion, 341: first convex part, 342: second convex part, 440: convex part, 441: lateral face, 442: apex, 443: edge.

Claims

1. A heat exchanger comprising:

a plurality of heat exchange modules arranged and spaced apart from each other in a first direction;
a header connected to end portions of the plurality of heat exchange modules, the end portions being located at ends of the plurality of heat exchange modules in a second direction crossing perpendicularly to the first direction, the plurality of heat exchange modules each including
a heat transfer tube extending in the second direction, and
a fin extending from an edge portion of the heat transfer tube in a third direction crossing perpendicularly to a plane parallel to the first direction and the second direction,
the fin including on its surface a plurality of convex parts each protruding in the first direction, and,
the plurality of convex parts each being provided to define a surface inclined relative to the second direction and the third direction.

2. The heat exchanger of claim 1,

wherein each of the plurality of convex parts is formed in a shape of a quadrangular pyramid, and
wherein edges of the plurality of convex parts are provided to extend continuously in the third direction.

3. The heat exchanger of claim 1,

wherein each of the plurality of convex parts is formed in a columnar shape that extends along a plane of the fin,
wherein a direction of length of each of the plurality of convex parts is inclined relative to the third direction.

4. The heat exchanger of claim 3, wherein the plurality of convex parts are arranged in the second direction, and are arranged in the third direction, the plurality of convex parts being all inclined in a same direction relative to the third direction.

5. The heat exchanger of claim 3,

wherein the fin is positioned on both sides of the heat transfer tube across the heat transfer tube in the third direction, and
wherein a direction of length of each of the plurality of convex parts provided to the fin positioned on one side of the heat transfer tube, and a direction of length of each of the plurality of convex parts provided to the fin positioned on an other side of the heat transfer tube have different inclinations from each other relative to the third direction.

6. The heat exchanger of claim 5, wherein in the fin, the direction of length of each of the plurality of convex parts provided to the fin positioned on the one side of the heat transfer tube, and the direction of length of each of the plurality of convex parts provided to the fin positioned on the other side of the heat transfer tube are symmetric about the heat transfer tube.

7. The heat exchanger of claim 3,

wherein the plurality of convex parts each include a first convex part and a second convex part, the first convex part and the second convex part having different inclinations from each other relative to the third direction and being spaced apart from each other in the second direction, and
wherein due to a combination of the first convex part and the second convex part, in the second direction, the plurality of convex parts are formed in a shape of a line that is bent at an angle at predetermined intervals at each of which the line doubles back in an opposite direction.

8. The heat exchanger of any one of claims 1 to 7,

wherein the fin has a root portion serving as a base portion connected to the heat transfer tube, and
wherein the root portion is offset toward protruding portions of the plurality of convex parts in the first direction, relative to a middle portion of a thickness of the heat transfer tube in the first direction.

9. The heat exchanger of any one of claims 1 to 8,

wherein the fin is positioned on both sides of the heat transfer tube across the heat transfer tube in the third direction, and
wherein in each of the plurality of heat exchange modules, at least one convex part of the plurality of convex parts provided to the fin positioned on

one side of the heat transfer tube has a top portion that is positioned outside the heat transfer tube in the first direction.

10. The heat exchanger of claim 9, wherein in each of the plurality of heat exchange modules, the plurality of convex parts provided to the fin positioned on an other side of the heat exchange module are positioned within a width of the heat transfer tube in the first direction. 5 10
11. The heat exchanger of any one of claims 1 to 10, wherein each of the plurality of heat exchange modules includes a flat portion, the flat portion being obtained by forming the fin to have a flat surface in both end portions in the second direction or the third direction. 15
12. The heat exchanger of any one of claims 1 to 11, wherein each of the plurality of convex parts is provided to have an inclination angle α that is less than an inclination angle β , the inclination angle α being defined as an angle formed by the convex part with the third direction, the inclination angle β being defined as an angle formed by the convex part with the second direction. 20 25
13. A refrigeration cycle apparatus comprising the heat exchanger of any one of claims 1 to 12. 30

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FIG. 1

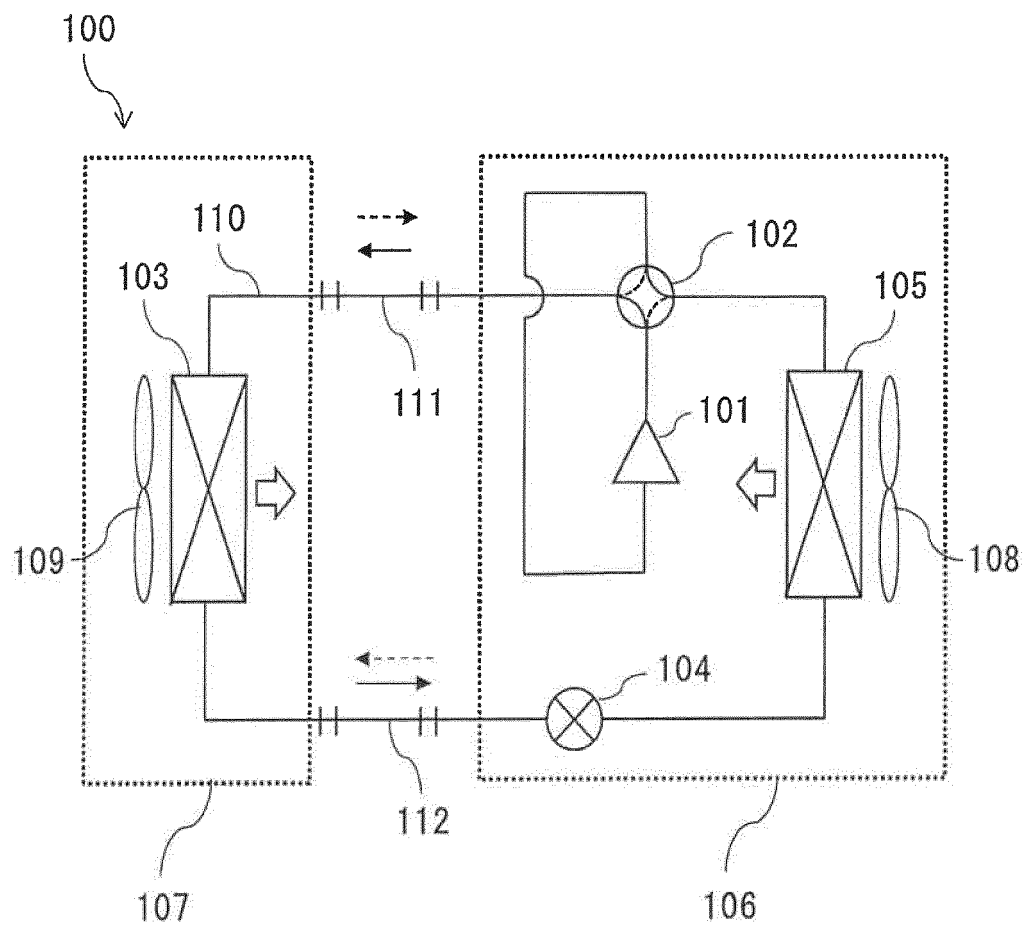


FIG. 2

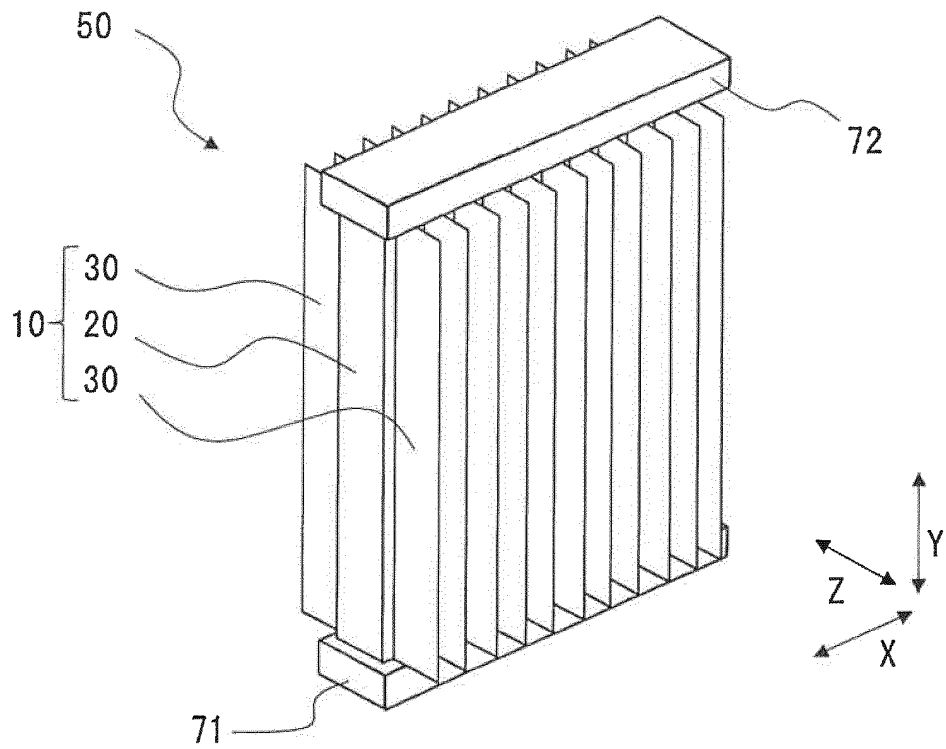


FIG. 3

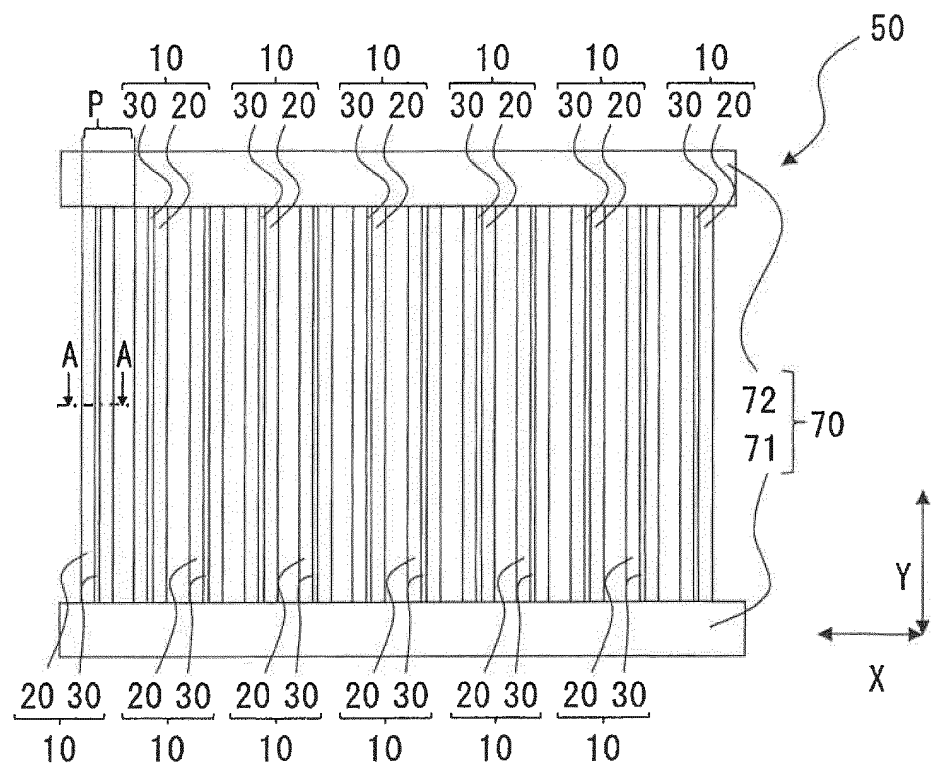
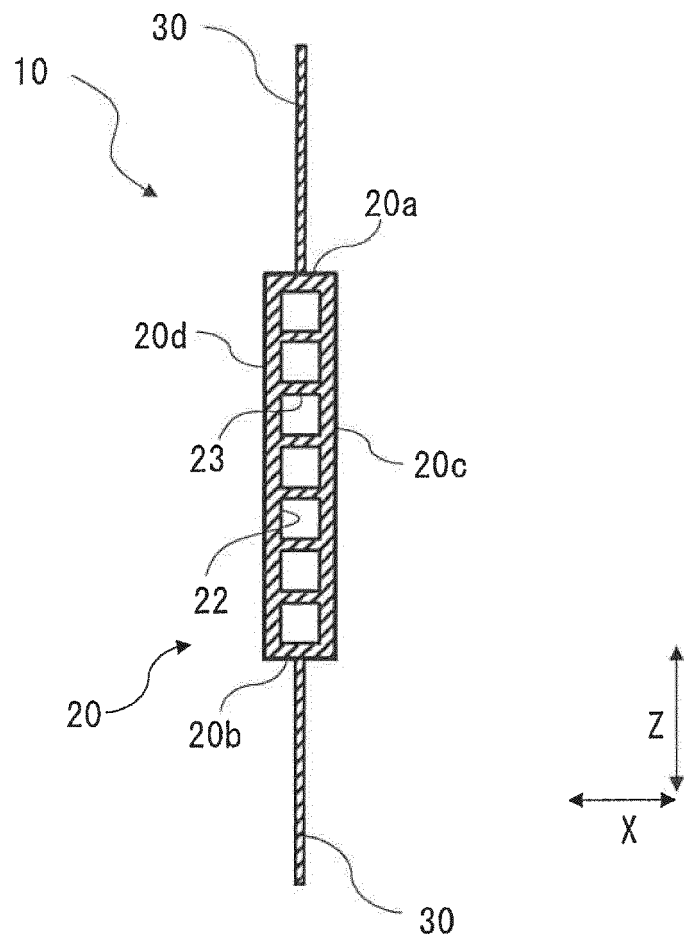


FIG. 4



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FIG. 5

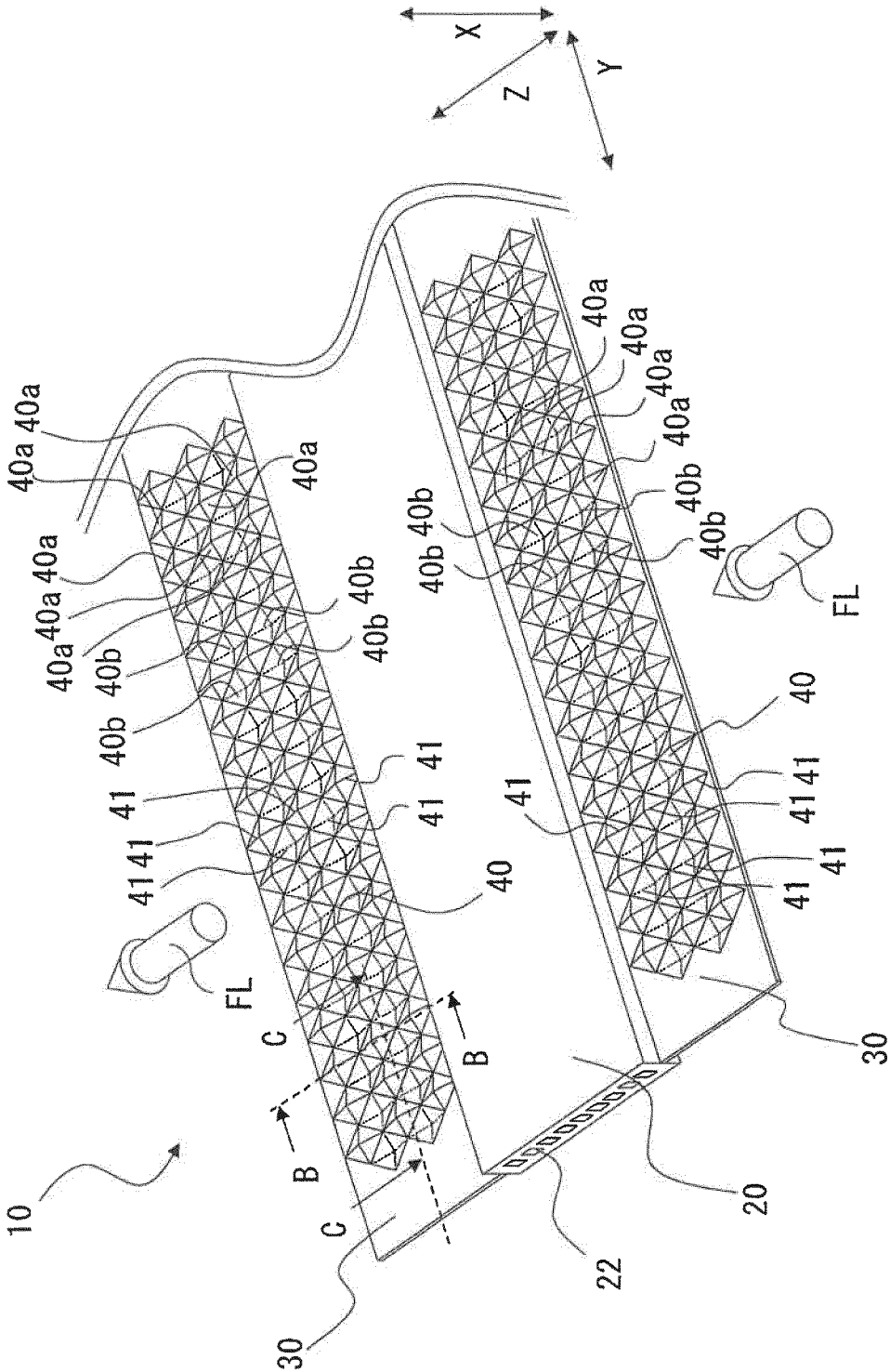


FIG. 6

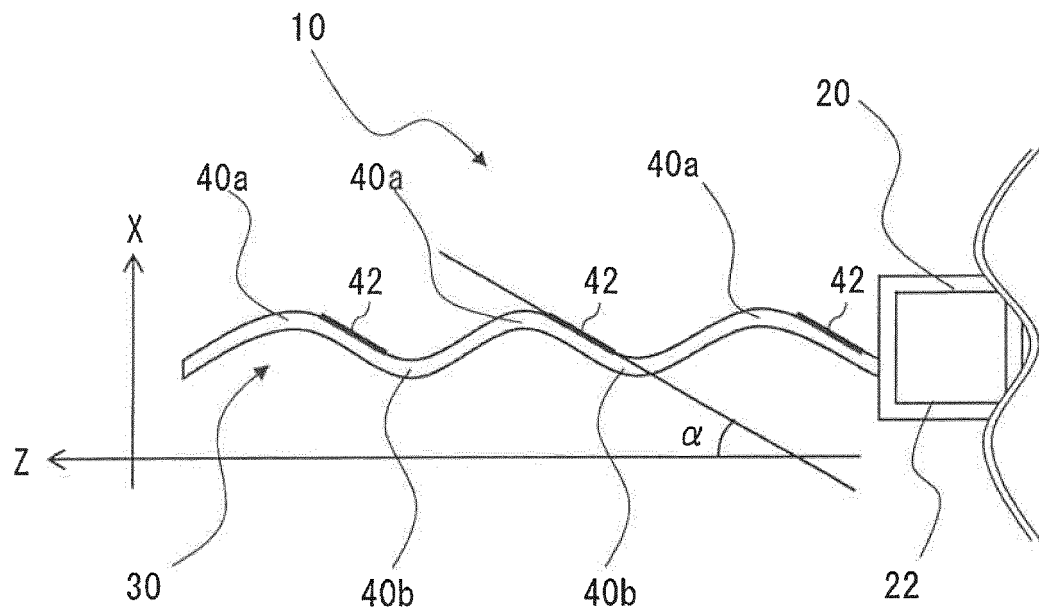


FIG. 7

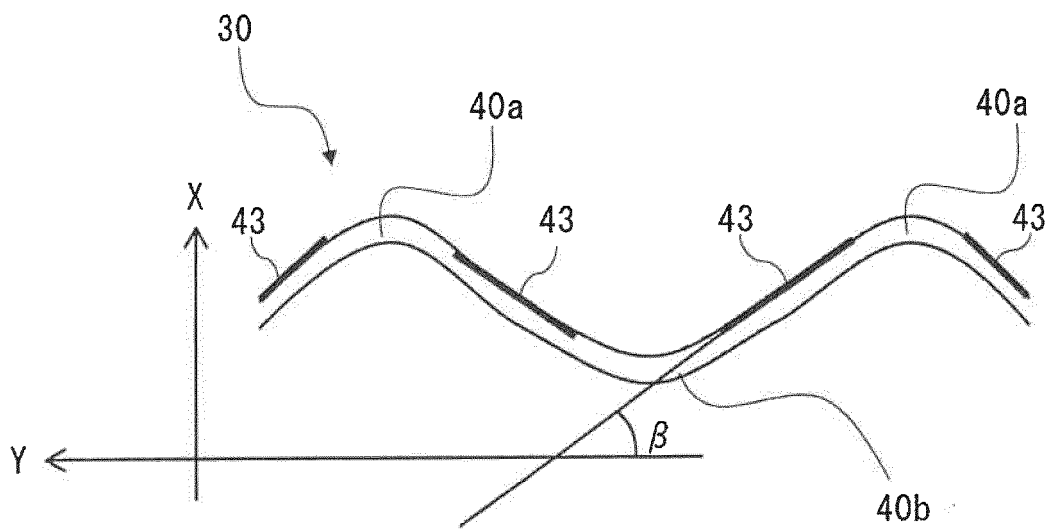


FIG. 8

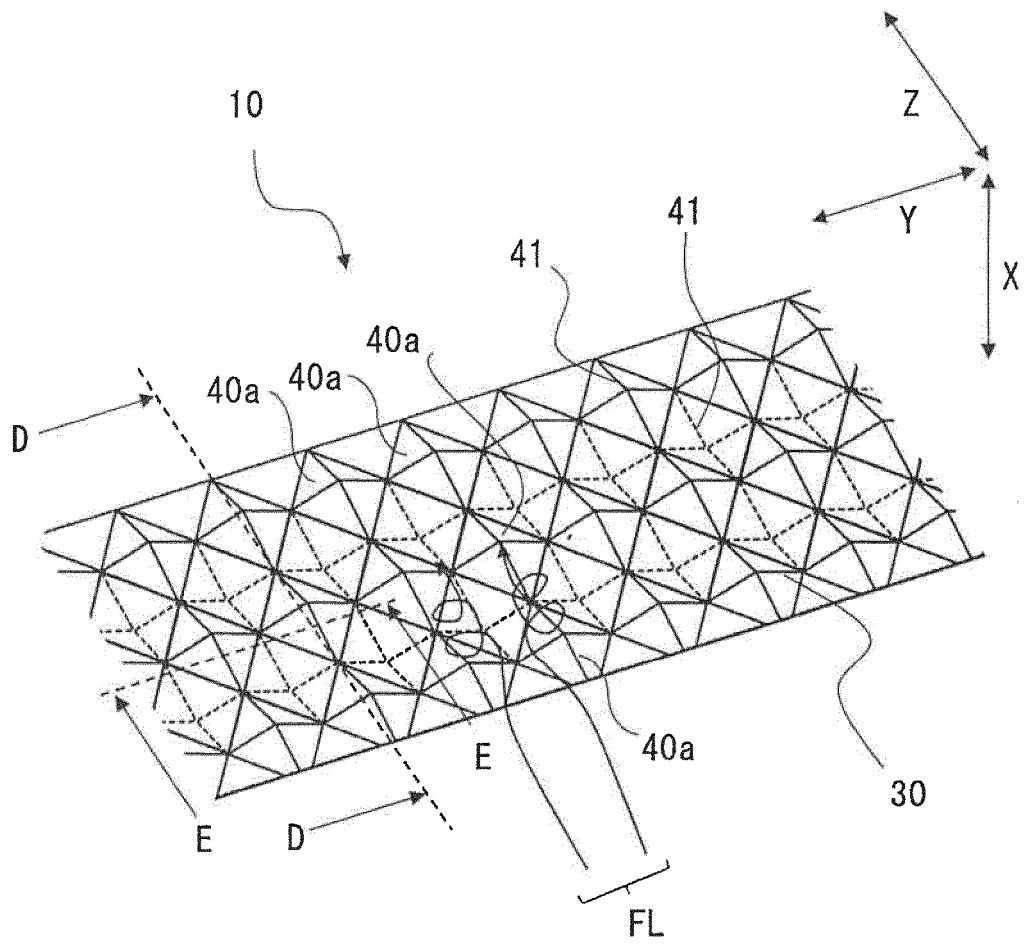


FIG. 9

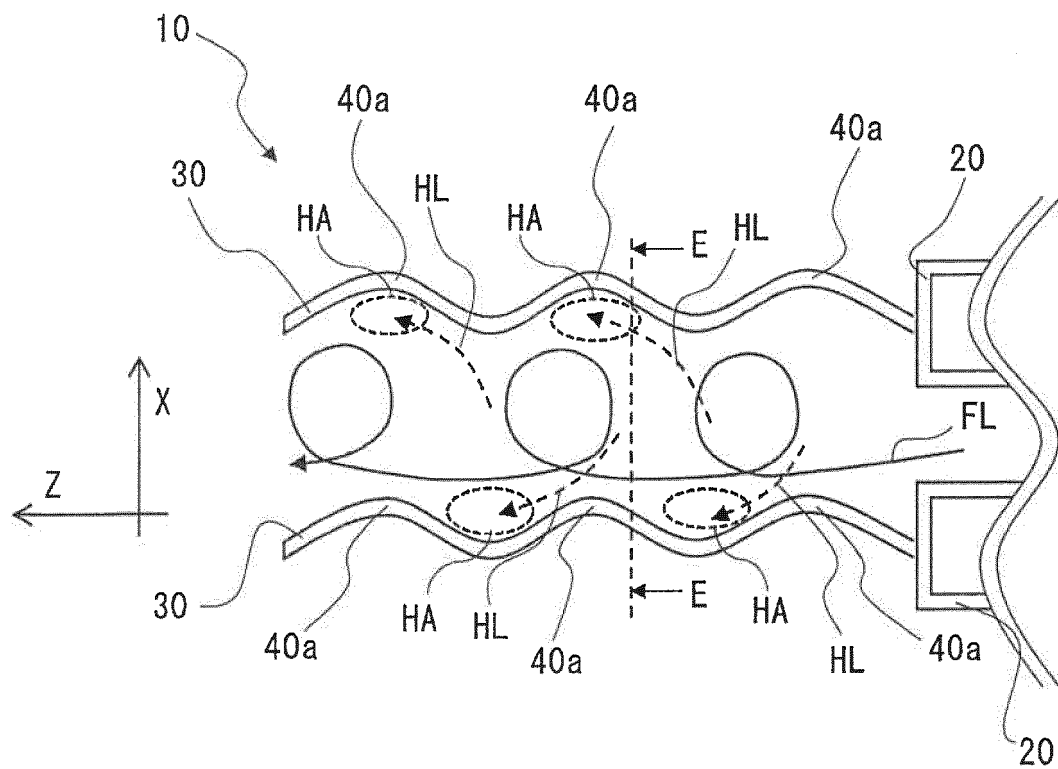


FIG. 10

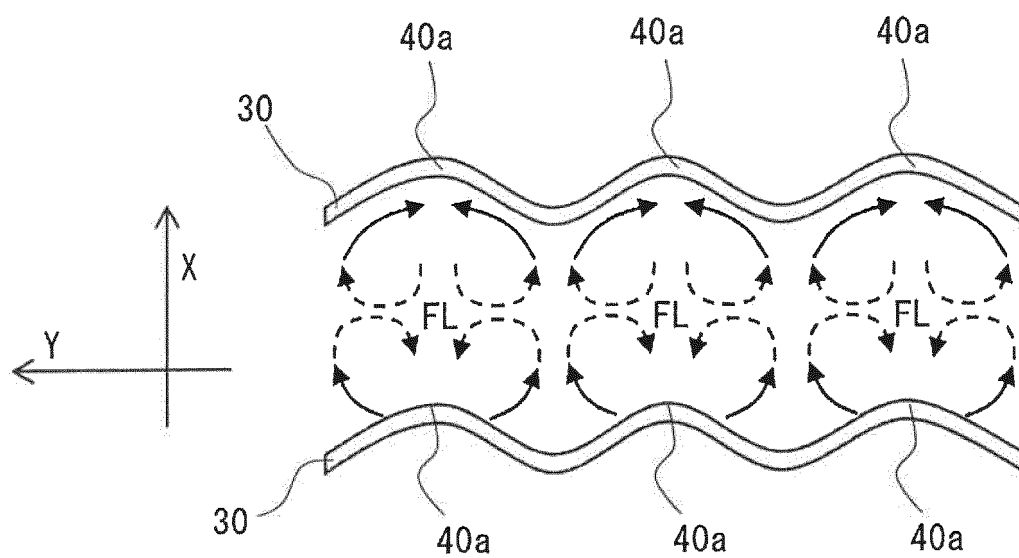


FIG. 11

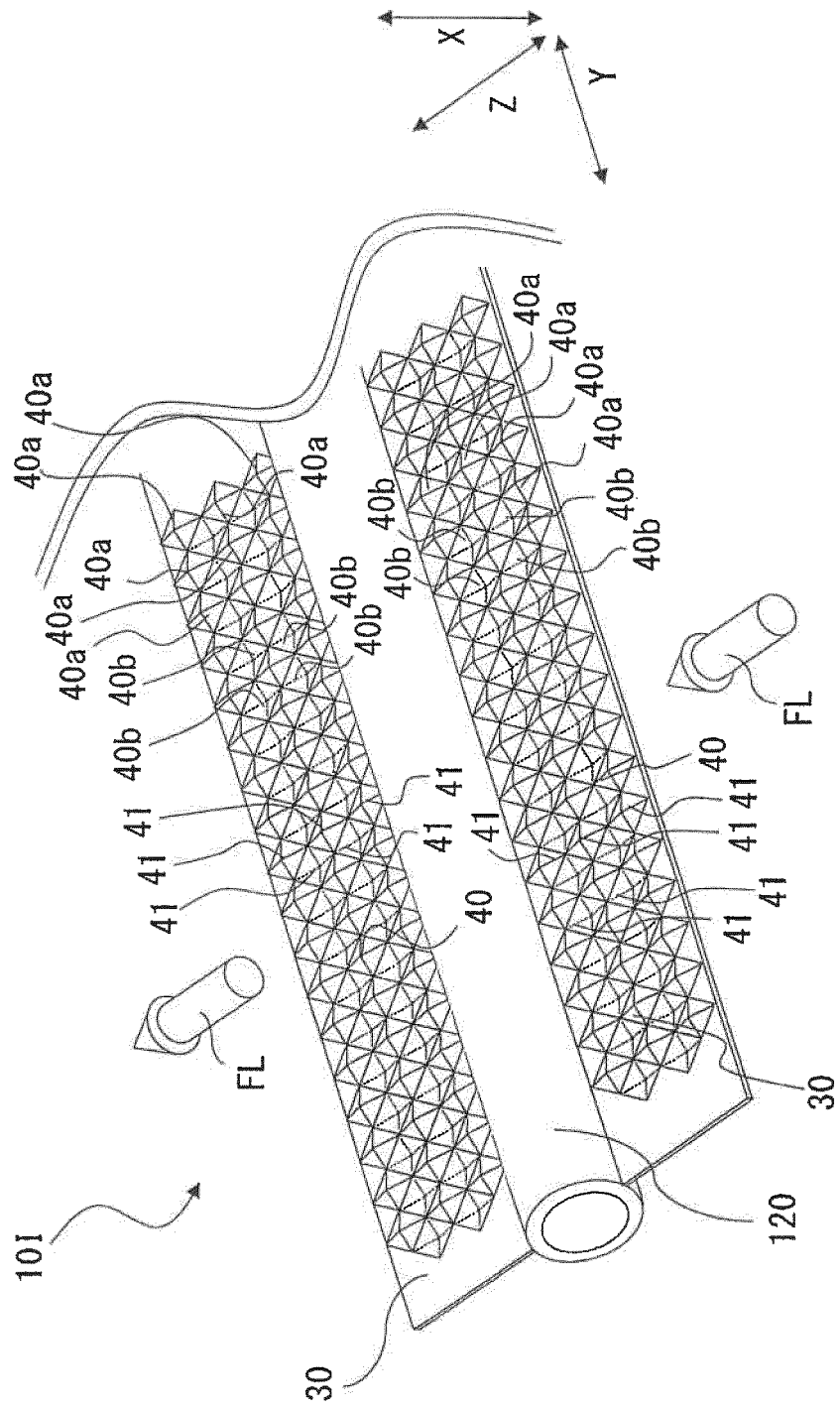


FIG. 12

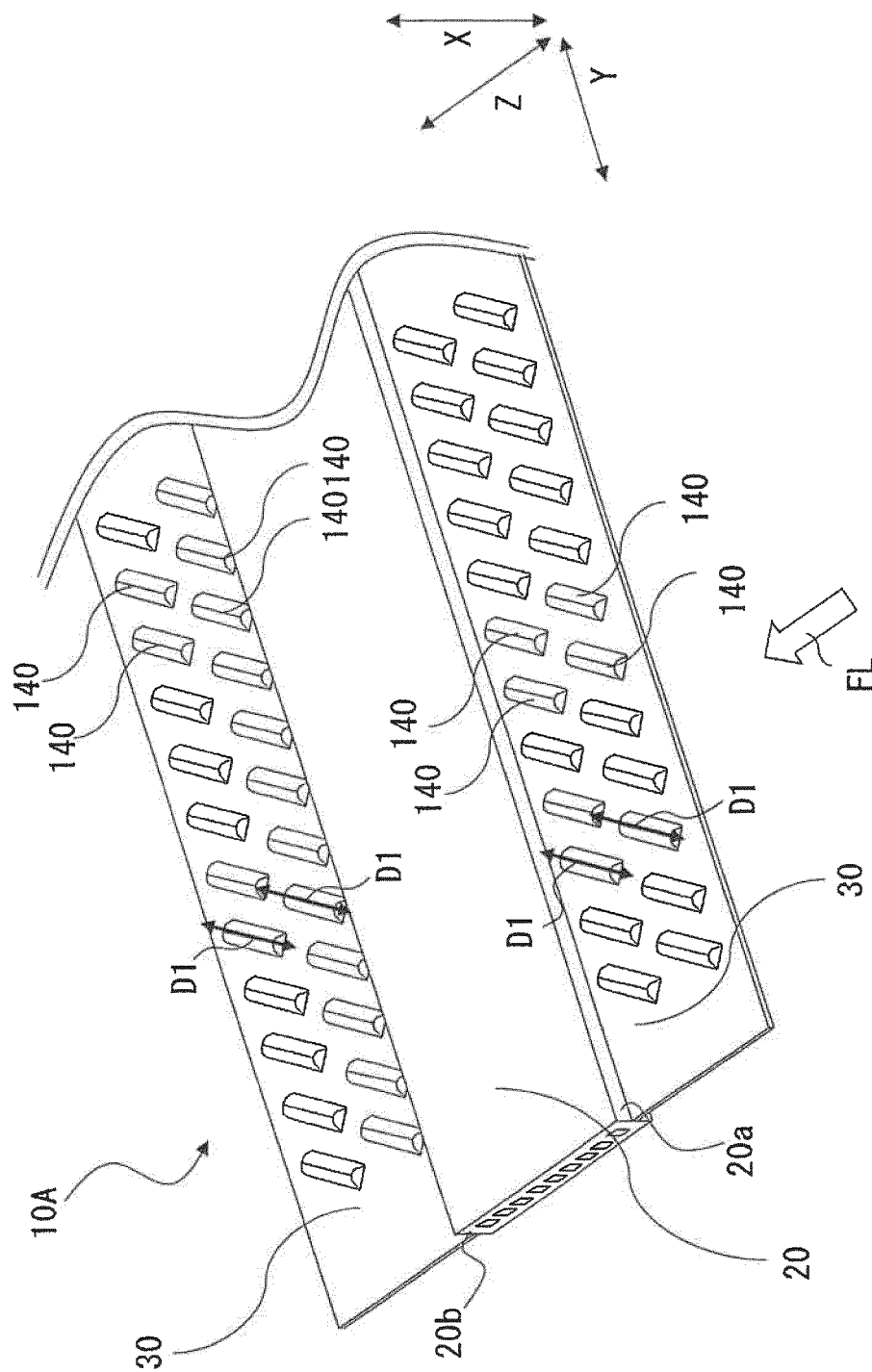


FIG. 13

FIG. 13

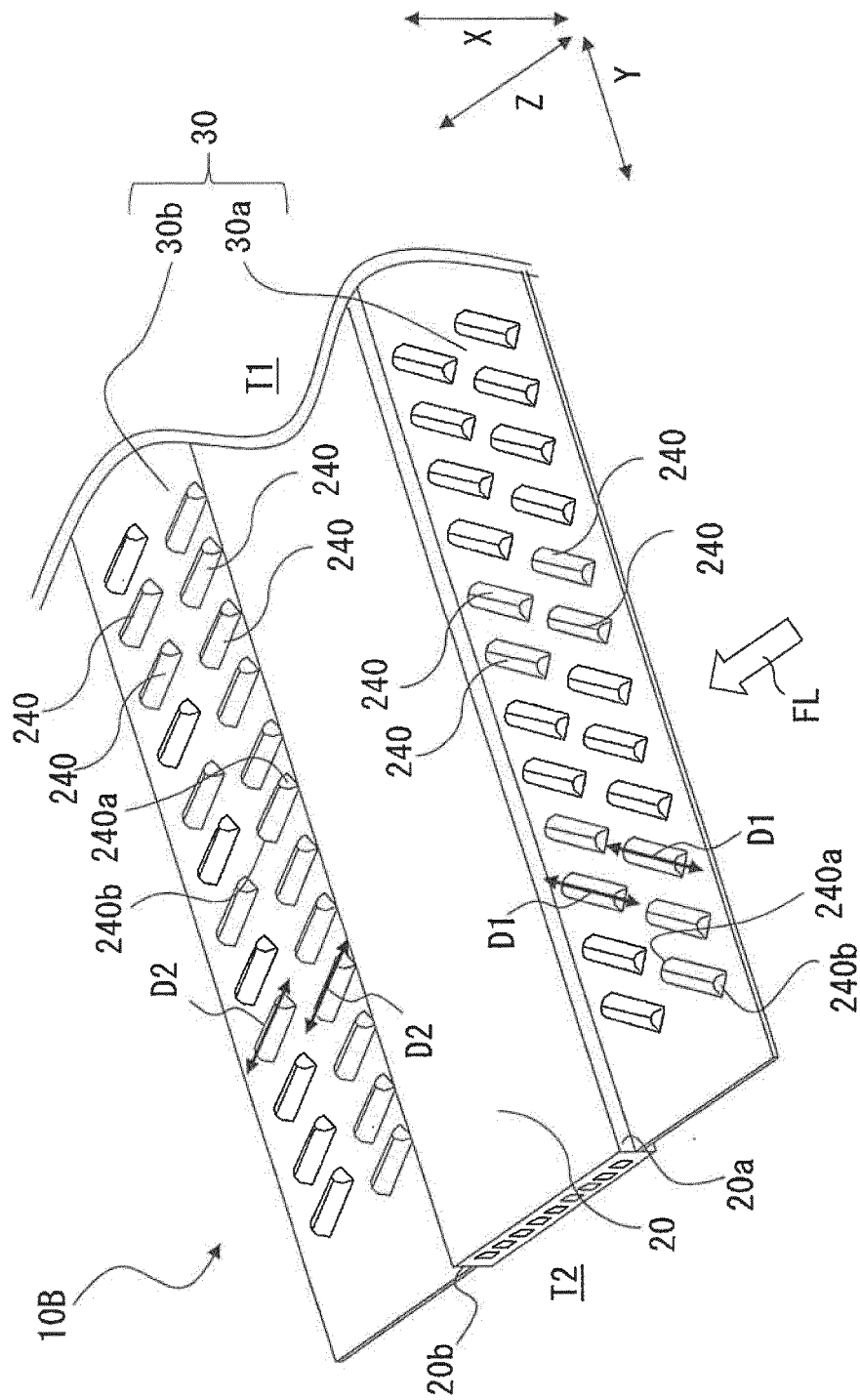


FIG. 14

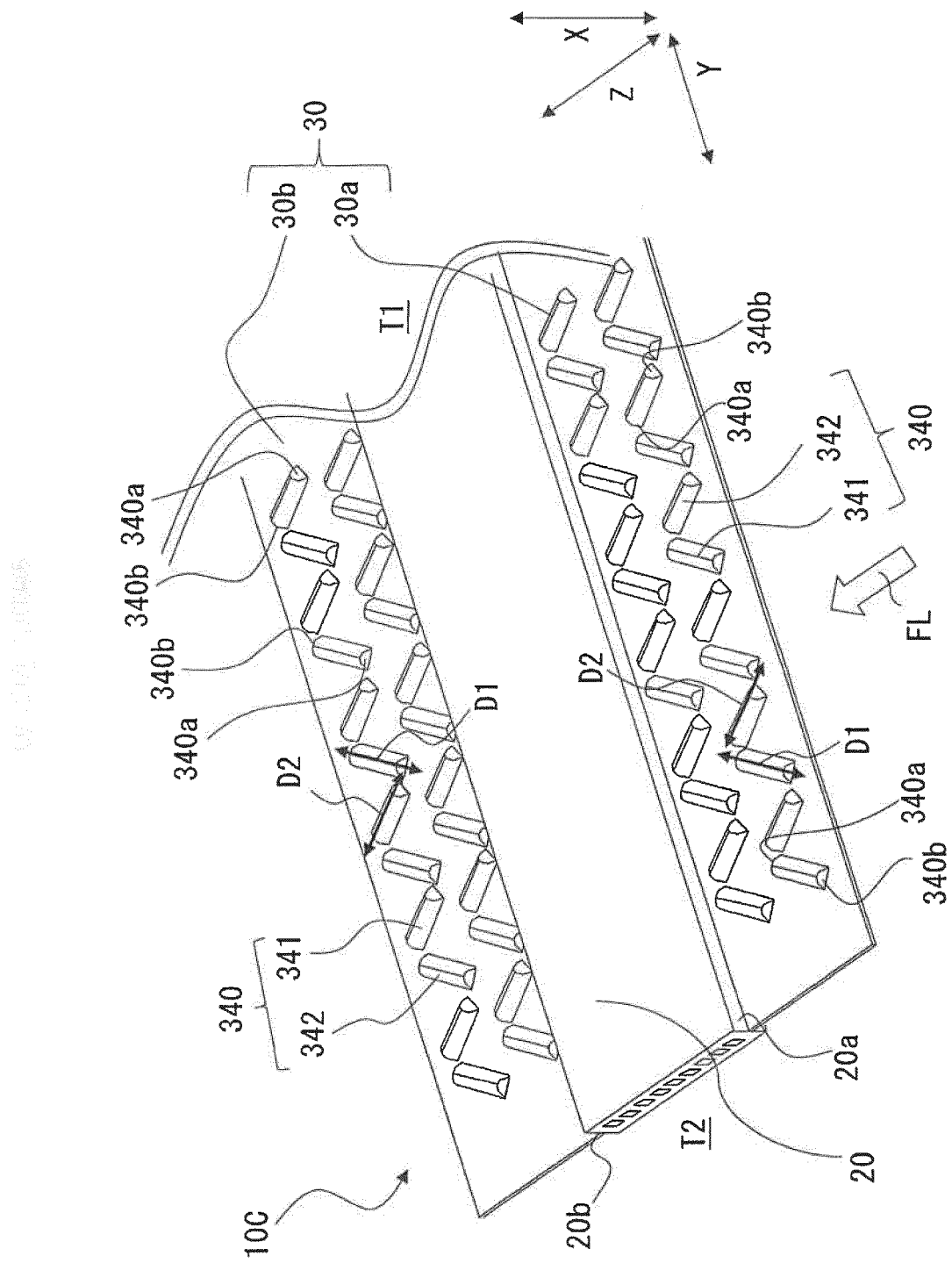


FIG. 15

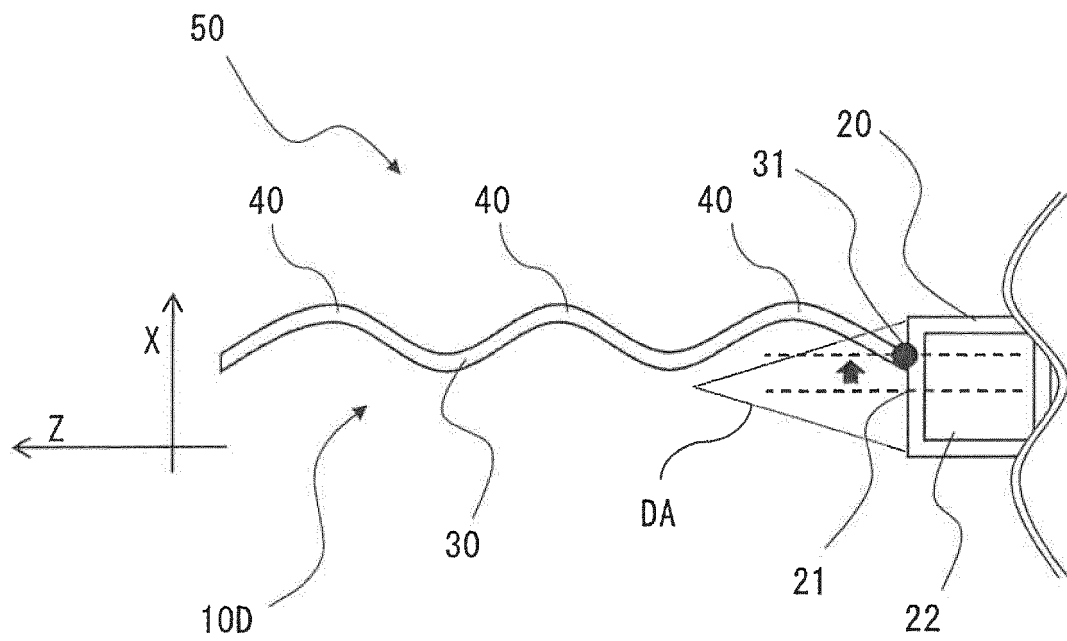


FIG. 16

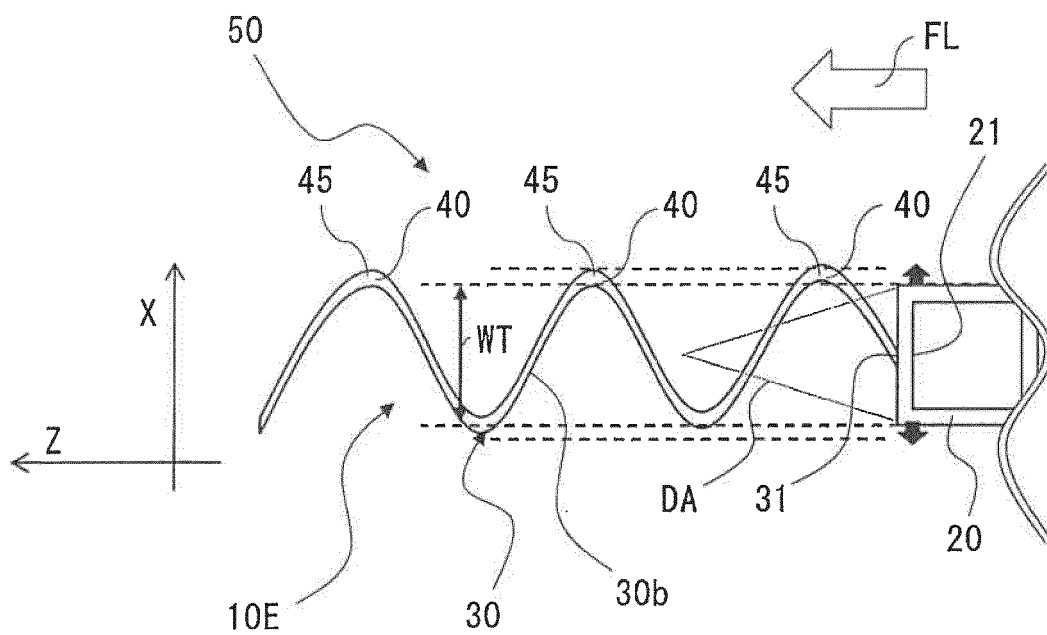
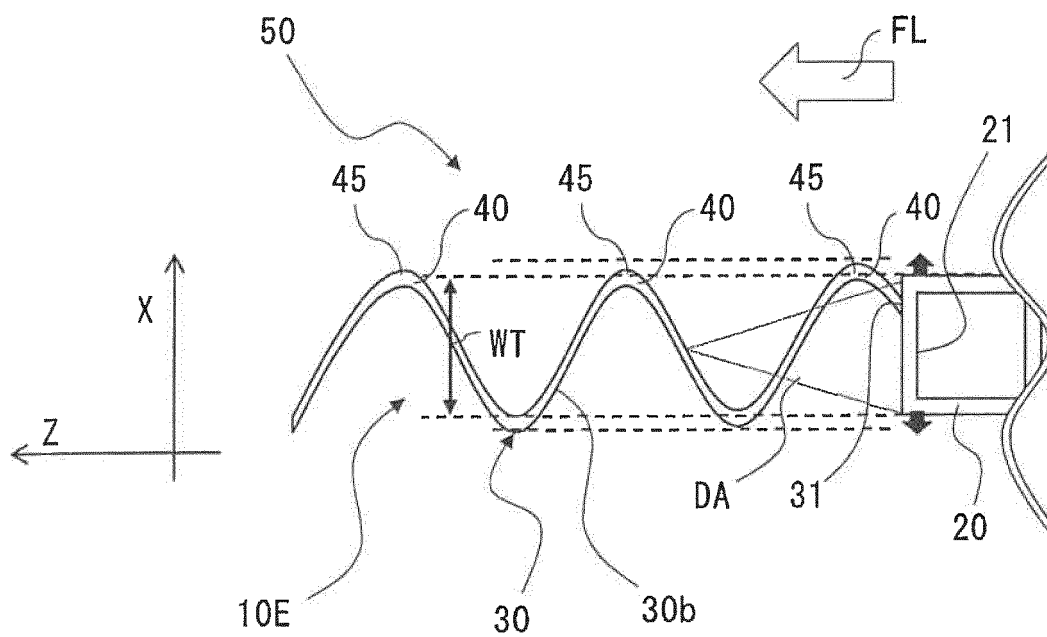


FIG. 17



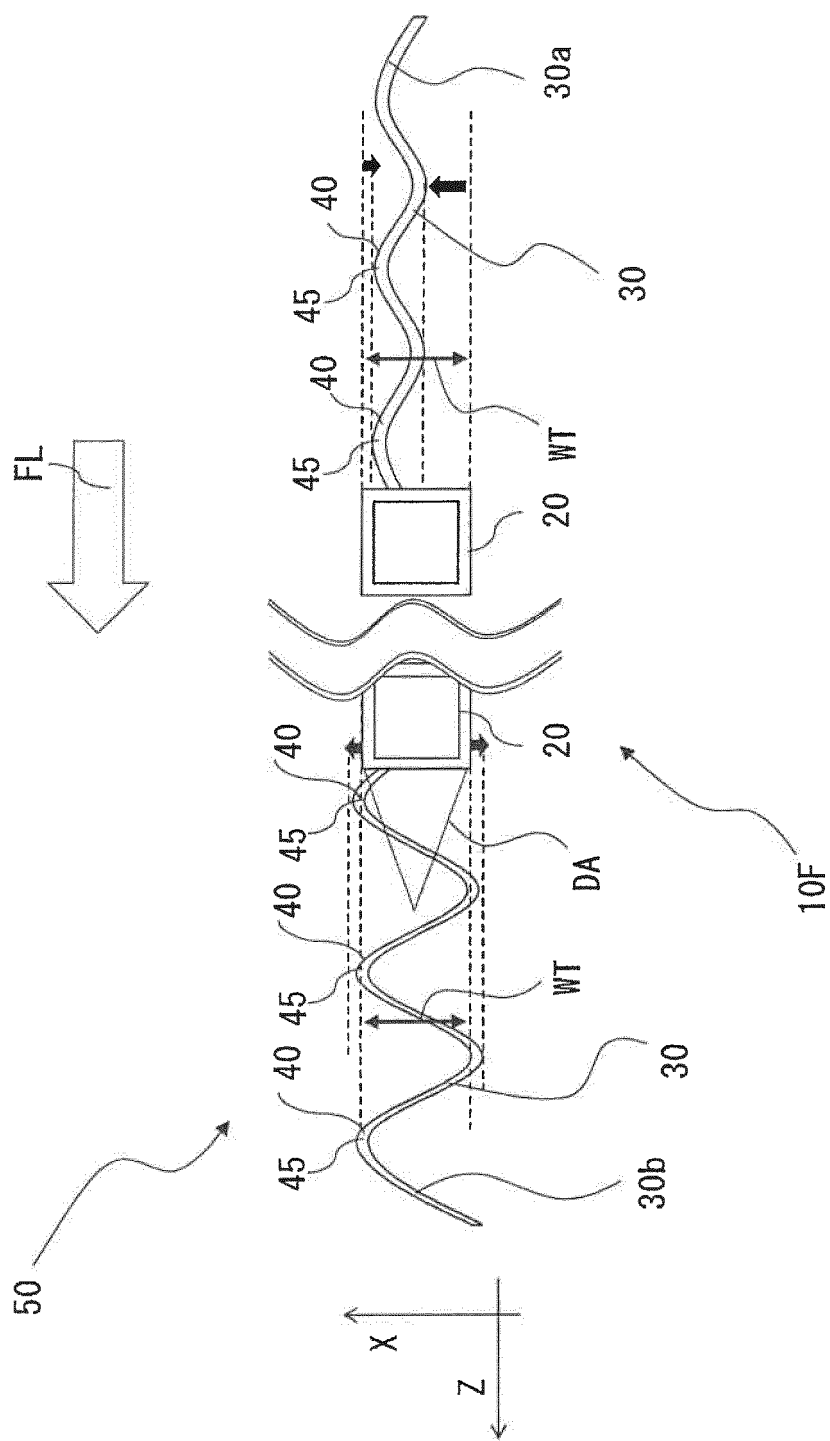





FIG. 19

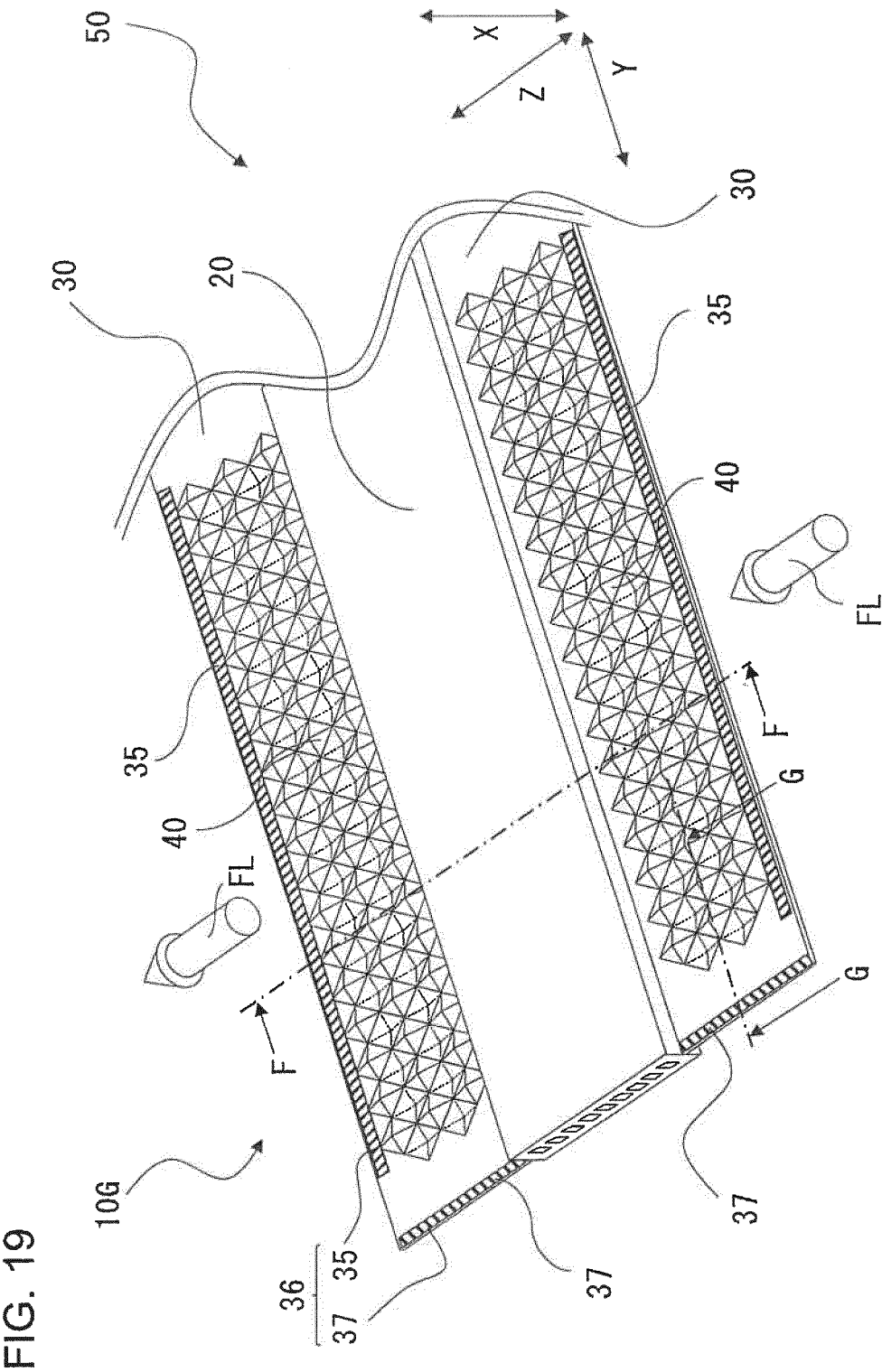


FIG. 20

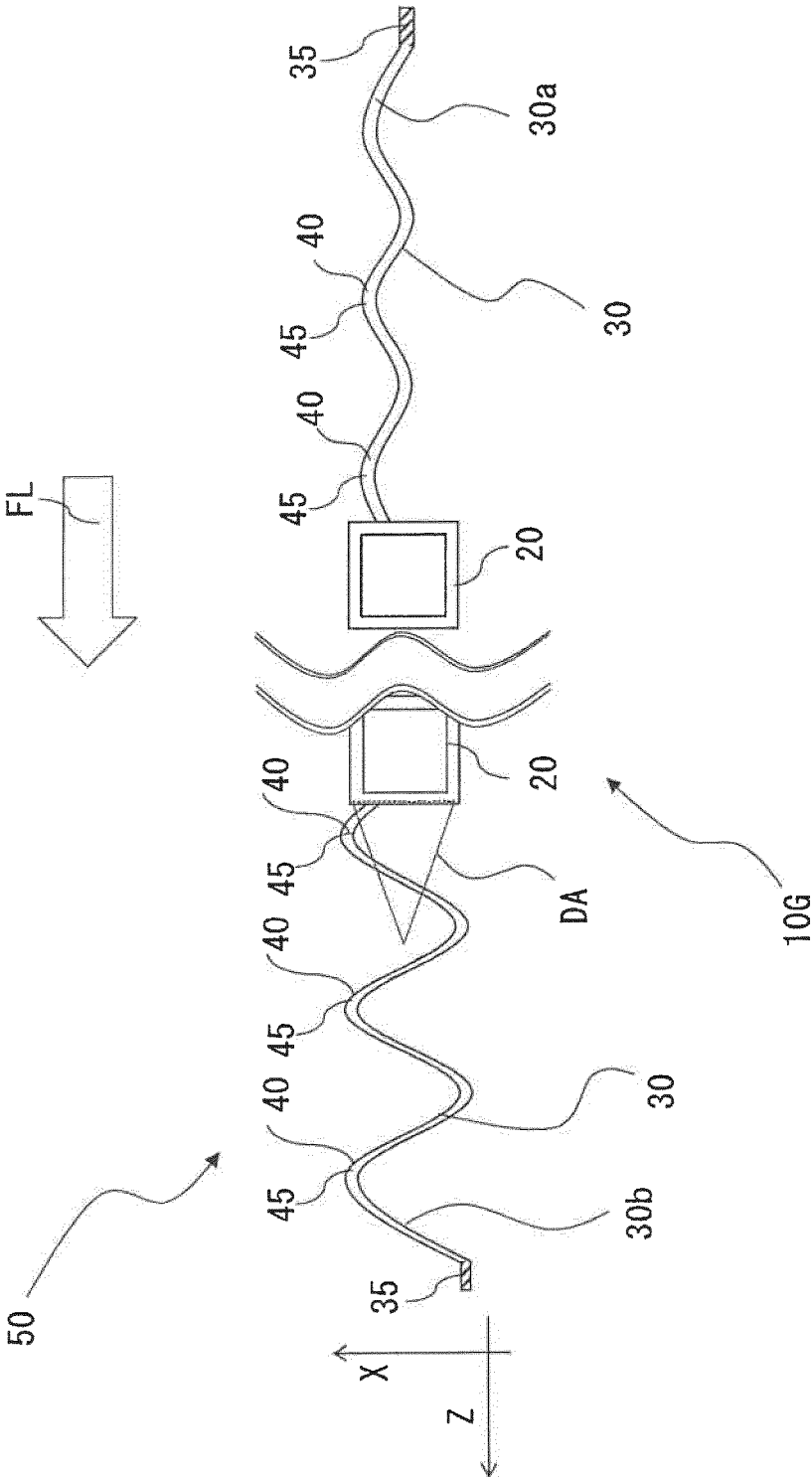


FIG. 21

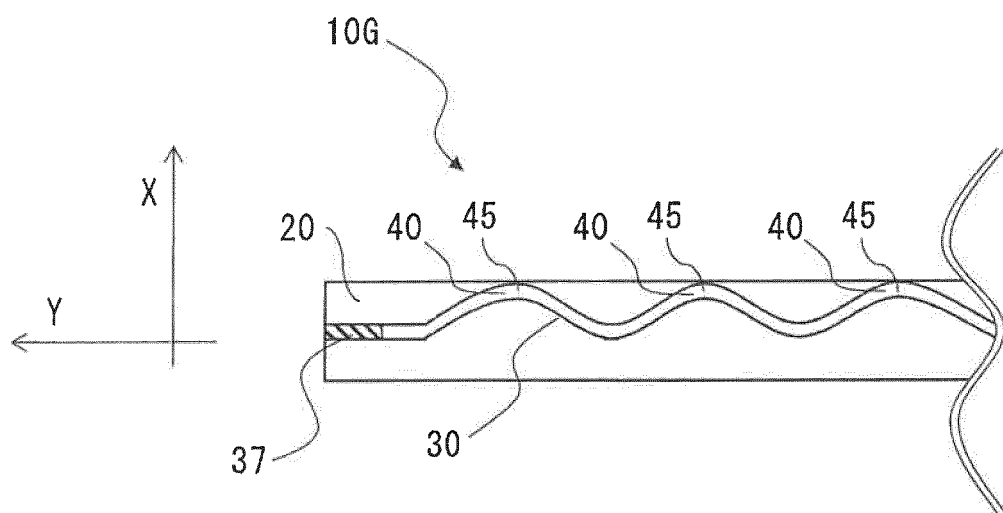


FIG. 22

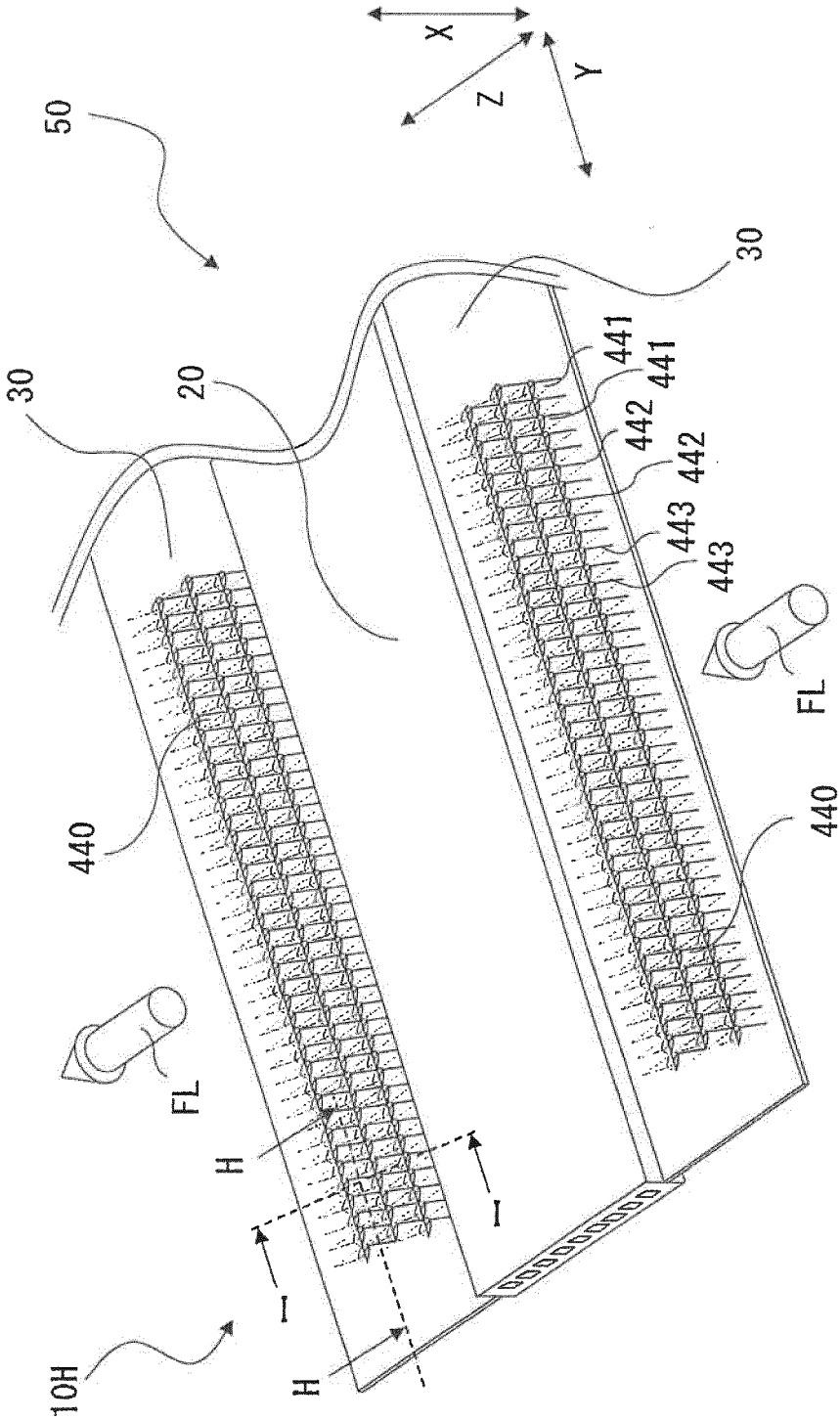


FIG. 23

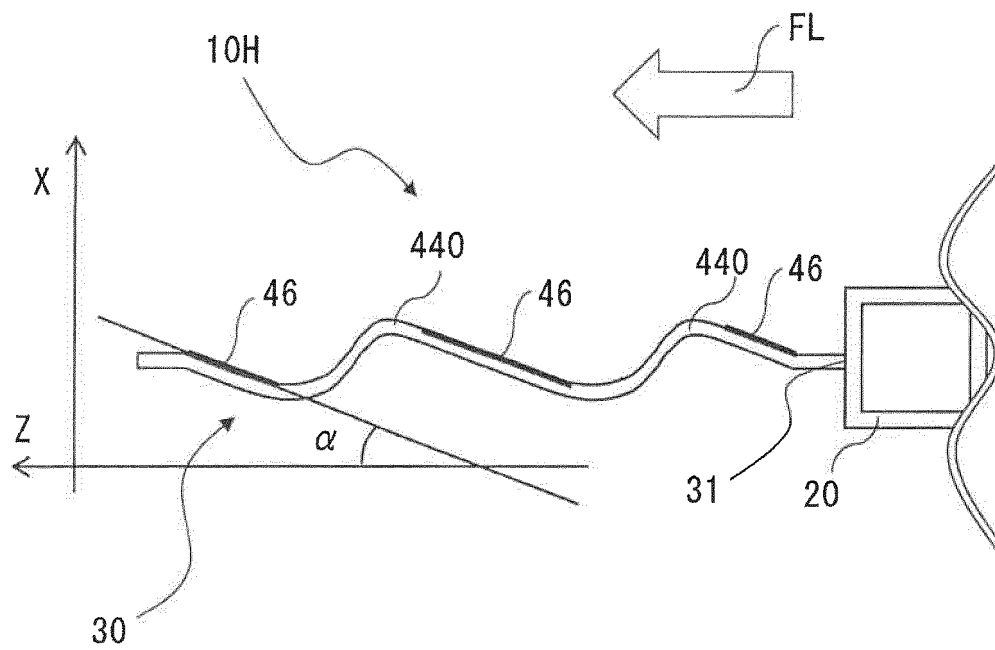
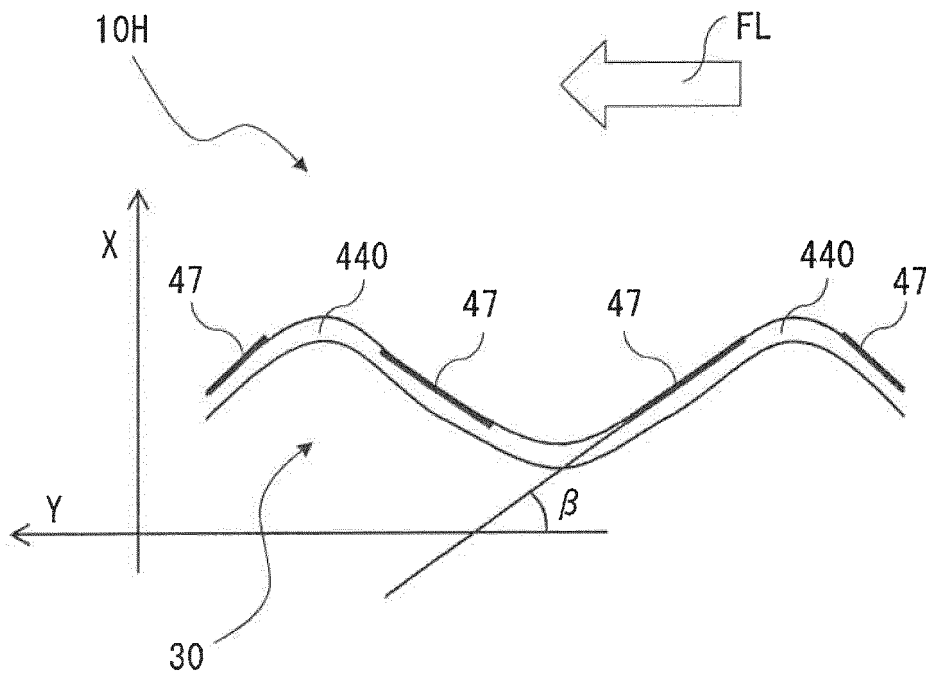


FIG. 24



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/026420

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F28F1/16 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. F28F1/16

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 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

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.
X Y A	JP 7-218172 A (SANDEN CORP.) 18 August 1995, paragraphs [0003]-[0012], fig. 1-6 & US 5647433 A, column 1, line 17 to column 3, line 4, fig. 1-6 & EP 06657711 A1 & CN 1107566 A	1 3-9, 11-13 10
X Y A	JP 9-159386 A (SANDEN CORP.) 20 June 1997, paragraphs [0005]-[0011], fig. 1-8 (Family: none)	1 3-9, 11-13 10
X Y A	JP 49-38256 A (UNION CARBIDE CORPORATION) 09 April 1974, description, page 12, upper left column, line 15 to upper right column, line 15, page 17, lower right column, line 12 to page 18, upper right column, line 9, fig. 8, 16 (Family: none)	1 8-9, 11-13 10

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

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Date of the actual completion of the international search
23.08.2019Date of mailing of the international search report
03.09.2019Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/026420

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Microfilm of the specification and drawings	1-2
Y	annexed to the request of Japanese Utility Model	8-9, 11-13
A	Application No. 068592/1977 (Laid-open No. 162945/1978) (NIPPON LIGHT METAL CO., LTD.) 20 December 1978, description, page 4, line 6 to page 5, line 13, fig. 1-3 (Family: none)	10
Y	JP 2015-528890 A (GENERAL ELECTRIC CO.) 01 October 2015, fig. 3-11 & US 2014/0027102 A1, fig. 3-11 & US 2017/0108291 A1 & WO 2014/018198 A1 & EP 2893277 A1 & CA 2879379 A1	3-9, 11-13
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 101143/1980 (Laid-open No. 24880/1982) (FURUTA, Takeo) 09 February 1982, fig. 5, 6 (Family: none)	8-9, 11-13
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 75306/1984 (Laid-open No. 185884/1985) (SHOWA ALUMINUM CORP.) 09 December 1985, fig. 2 (Family: none)	8-9, 11-13

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008202896 A [0004]