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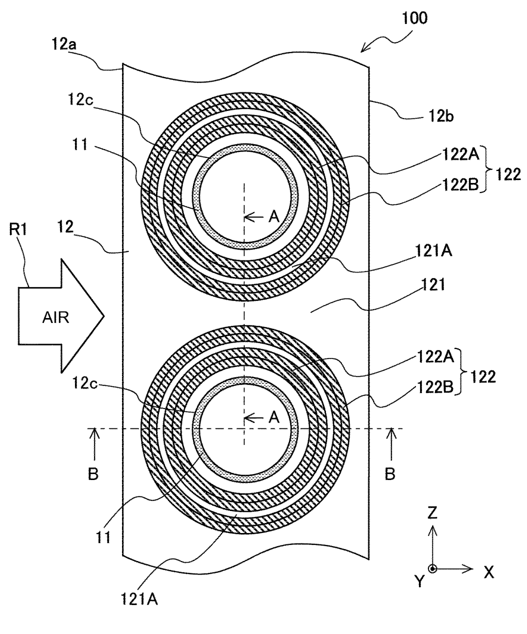
(54) **HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE**

(57) A heat exchanger includes a plurality of fins spaced apart from one another in a first direction and a plurality of heat transfer tubes penetrating through the plurality of fins, the plurality of heat transfer tubes being spaced apart from one another in a second direction crossing the first direction. Each of the plurality of fins includes a fin base surface that is flat and a plurality of fin projections. The plurality of fin projections include inner fin projections provided to separately surround each of the plurality of heat transfer tubes, the inner fin projections protruding in the first direction from the fin base surface, and outer fin projections provided to separately surround each of the inner fin projections, the outer fin projections protruding in the first direction from the fin base surface.

FIG. 4



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Description

Technical Field

[0001] The present disclosure relates to a heat exchanger and a refrigeration cycle apparatus including the same.

Background Art

[0002] There has been known a technique for improving the heat transfer performance of a fin-and-tube heat exchanger by providing projections on a fin surface to control the direction of flow of air.

[0003] For example, in a heat exchanger described in Patent Literature 1, projections for preventing airflow separation are provided around each heat transfer tube to narrow a dead water region in a wake flow portion of the heat transfer tube to bring about improvement in heat transfer performance. The term "dead water region" here means a region into which air does not flow and where there is a decrease in heat transfer coefficient. In Patent Literature 1, a collision of an airflow with the projections around the heat transfer tube causes air to flow into the wake flow portion of the heat transfer tube, thus narrowing the dead water region in the wake flow portion of the heat transfer tube.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 58-158496

Summary of Invention

Technical Problem

[0005] In Patent Literature 1, the projections are provided at positions at an angle of ±70 degrees to ±80 degrees to a stagnation point directed toward the center of the heat transfer tube, with the result that the projections are sparsely provided around the heat transfer tube. For this reason, in Patent Literature 1, it is hard to secure, around the heat transfer tube, a region in which to provide additional projections for improving the strength of each fin. The incapability of providing additional projections for improving the strength of the fins causes the fin to bend in a longitudinal direction when worked on. Further, the projections of Patent Literature 1 per se cannot bring about sufficient improvement in heat transfer coefficient, as the surface area of the fin is small in enlargement factor.

[0006] The present disclosure was made to solve such problems and has as an object to provide a heat exchanger with improvement in longitudinal strength of each fin and improvement in heat transfer coefficient and a refrigeration cycle apparatus including the same.

Solution to Problem

[0007] A heat exchanger according to an embodiment of the present disclosure includes a plurality of fins spaced apart from one another in a first direction and a plurality of heat transfer tubes penetrating through the plurality of fins, the plurality of heat transfer tubes being spaced apart from one another in a second direction crossing the first direction. Each of the plurality of fins includes a fin base surface that is flat and a plurality of fin projections. The plurality of fin projections include inner fin projections provided to separately surround each of the plurality of heat transfer tubes, the inner fin projections protruding in the first direction from the fin base surface, and outer fin projections provided to separately surround each of the inner fin projections, the outer fin projections protruding in the first direction from the fin base surface.

[0008] A refrigeration cycle apparatus according to an embodiment of the present disclosure includes the heat exchanger as a condenser or an evaporator. Advantageous Effects of Invention

[0009] In a heat exchanger according to an embodiment of the present disclosure, the inner fin projections and the outer fin projections are provided around the heat transfer tubes. The inner fin projections and the outer fin projections extend in a longitudinal direction of the fin to surround the heat transfer tubes, thus bringing about improvement in longitudinal strength of the fin. This makes it possible to cause the fin to bend less in the longitudinal direction when worked on. Further, the inner fin projections and the outer fin projections, which are provided around the heat transfer tubes, enlarge the surface area of the fin base surface, thus bringing about improvement in heat transfer coefficient on the surface of the fin 12. This makes it possible to improve the heat transfer performance of the heat exchanger.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a perspective view showing a configuration of a heat exchanger 100 according to Embodiment 1.

[Fig. 2] Fig. 2 is a partial sectional side view showing only a basic configuration of the heat exchanger 100 of Fig. 1.

[Fig. 3] Fig. 3 is a refrigerant circuit diagram showing an example of a configuration of a refrigeration cycle apparatus 1 according to Embodiment 1.

[Fig. 4] Fig. 4 is a partial sectional side view showing a fin 12 of the heat exchanger 100 according to Embodiment 1.

[Fig. 5] Fig. 5 is a cross-sectional view taken along line A-A in Fig. 4.

[Fig. 6] Fig. 6 is a cross-sectional view taken along line B-B in Fig. 4.
[Fig. 7] Fig. 7 is a cross-sectional view showing Modification 1 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 8] Fig. 8 is a partial sectional side view showing Modification 2 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 9] Fig. 9 is a partial sectional side view showing Modification 3 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 10] Fig. 10 is a partial sectional side view showing Modification 4 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 11] Fig. 11 is a partial sectional side view showing Modification 5 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 12] Fig. 12 is a partial sectional side view showing Modification 6 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 13] Fig. 13 is a partial sectional side view showing Modification 7 of a fin 12 of the heat exchanger 100 according to Embodiment 1.
[Fig. 14] Fig. 14 is a cross-sectional view taken along line A-A in Fig. 13.
[Fig. 15] Fig. 15 is a partial sectional side view showing a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 16] Fig. 16 is a cross-sectional view taken along line A-A in Fig. 15.
[Fig. 17] Fig. 17 is a cross-sectional view taken along line C-C in Fig. 15.
[Fig. 18] Fig. 18 is a cross-sectional view showing Modification 1 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 19] Fig. 19 is a partial sectional side view showing Modification 2 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 20] Fig. 20 is a cross-sectional view taken along line A-A in Fig. 19.
[Fig. 21] Fig. 21 is a partial sectional side view showing Modification 3 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 22] Fig. 22 is a cross-sectional view taken along line A-A in Fig. 21.
[Fig. 23] Fig. 23 is a partial sectional side view showing Modification 4 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 24] Fig. 24 is a cross-sectional view taken along line A-A in Fig. 23.
[Fig. 25] Fig. 25 is a partial sectional side view showing Modification 5 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 26] Fig. 26 is a cross-sectional view taken along line C-C in Fig. 25.
[Fig. 27] Fig. 27 is a partial sectional side view showing Modification 6 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 28] Fig. 28 is a cross-sectional view taken along line C-C in Fig. 27.
[Fig. 29] Fig. 29 is a partial sectional side view showing Modification 7 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 30] Fig. 30 is a cross-sectional view taken along line C-C in Fig. 29.
[Fig. 31] Fig. 31 is a partial sectional side view showing Modification 8 of a fin 12 of the heat exchanger 100 according to Embodiment 2.
[Fig. 32] Fig. 32 is a cross-sectional view taken along line C-C in Fig. 31. Description of Embodiments

[0011] The following describes, with reference to the drawings, a heat exchanger according to an embodiment of the present disclosure and a refrigeration cycle apparatus including the same. The present disclosure is not limited to the following embodiments but may be modified variously without departing from the scope of the present disclosure. The present disclosure encompasses all combinations of combinable ones of components that are described in the following embodiments. Further, constituent elements given identical reference signs in the drawings are identical or equivalent to each other, and these signs are adhered to throughout the full text of the description. A dimensional relationship of each constituent element relative to another, the shape of each constituent element, or other features in the drawings may be different from actual ones.

Embodiment 1.

[0012] The following describes, with reference to the drawings, a heat exchanger 100 according to Embodiment 1 and a refrigeration cycle apparatus 1 including the same.

[Basic Configuration of Heat Exchanger 100]

[0013] Fig. 1 is a perspective view showing a configuration of a heat exchanger 100 according to Embodiment 1. The heat exchanger 100 is a fin-and-tube heat exchanger. As shown in Fig. 1, the heat exchanger 100 includes a plurality of heat transfer tubes 11 and a plurality of fins 12. The following description uses each of the nouns "heat transfer tube 11" and "fin 12" in either the singular form or the plural form.

[0014] As shown in Fig. 1, each of the fins 12 is a rectangular flat-plate element. Those fins 12 are placed at regular spacings from one another in a Y direction to form a space through which air flows. In the following, the spacings are called "fin pitches". The fin pitches do not need to be equal to one another but may be different from one another. The fin pitches are each a center-to-center distance between adjacent ones of the fins 12 in a thickness direction. Air flows along principal surfaces of the fins 12 as indicated by an arrow R1 in Fig. 1. The fins 12 are constituted, for example, by aluminum but are not limited to particular materials. It should be noted that the direction in which air flows as indicated by the arrow R1 is called "X direction (third direction)". Further, a longitudinal direction of the fins 12 is called "Z direction (second direction)". Furthermore, the direction in which the fins 12 are stacked is called "Y direction (first direction)". The X direction and the Z direction are orthogonal to each other. Further, the X direction and the Y direction are orthogonal to each other. Furthermore, the Y direction and the Z direction are orthogonal to each other. It should be noted that a transverse direction of the fins 12 is sometimes referred to as "X direction (third direction)". The Z direction is for example a vertical direction. Assuming that the X direction is a column-wise direction in which columns of heat transfer tubes 11 are arranged and that the Z direction is a row-wise direction in which the heat transfer tubes 11 are arranged in rows, the heat transfer tubes 11 are arranged in one column and twelve rows in the example shown in Fig. 1. It should be noted that the column count and row count of heat transfer tubes 11 are not limited to these counts. For example, the heat transfer tubes 11 may be arranged in two or more columns through the fins 12. It should be noted that Fig. 1 shows a case in which a longitudinal direction of the heat transfer tubes 11 extends in the Y direction. The Y direction is for example a horizontal direction. However, this case is not intended to impose any limitation. That is, the longitudinal direction of the heat transfer tubes 11 may extend in a vertical direction. In that case, the longitudinal direction of the fins 12 is a horizontal direction.

[0015] As shown in Fig. 1, the plurality of heat transfer tubes 11 are disposed to penetrate through the fins 12. Accordingly, the longitudinal direction of the heat transfer tubes 11 is the Y direction. Further, those heat transfer tubes 11 are placed parallel to one another at regular spacings from one another in the Z direction. In the following, the spacings are called "tube pitches". The tube pitches do not need to be equal to one another but may be different from one another. The tube pitches are each a center-to-center distance between adjacent ones of the heat transfer tubes 11 in the Z direction. As indicated by arrows R2 in Fig. 1, refrigerant flows through the heat transfer tubes 11. Ones of the heat transfer tubes 11 that are adjacent to each other in the Z direction have their ends connected to each other by a U-tube 11a as shown in Fig. 1. This causes the plurality of heat transfer tubes 11 to be combined to make a single tube so that the refrigerant sequentially flows. Alternatively, the heat transfer tubes 11 do not need to be combined to make a single tube. The heat transfer tubes 11 are constituted a highly thermal conductive metal such as copper or a copper alloy but are not limited to particular materials.

[0016] Fig. 2 is a partial sectional side view showing only a basic configuration of the heat exchanger 100 of Fig. 1. Fig. 2 shows a cross-section taken at one place in the Y direction. Specifically, Fig. 2 shows the principal surface of a fin 12 and cross-sections of heat transfer tubes 11. Each of the heat transfer tubes 11 is constituted, for example, by a circular tube or a flat tube. Figs. 1 and 2 show a case in which the heat transfer tubes 11 are circular tubes.

[0017] The heat exchanger 100 exchanges heat between air flowing along the principal surfaces of the fins 12 and refrigerant flowing through the heat transfer tubes 11. The heat exchanger 100 is placed so that air flows in the X direction.

[Basic Configuration of Refrigeration Cycle Apparatus 1]

[0018] The heat exchanger 100 shown in Fig. 1 is used, for example, in a refrigeration cycle apparatus 1. Fig. 3 is a refrigerant circuit diagram showing an example of a configuration of the refrigeration cycle apparatus 1 according to Embodiment 1. As shown in Fig. 3, the refrigeration cycle apparatus 1 includes a heat source side unit 2 and a load side unit 3.

[0019] As shown in Fig. 3, the heat source side unit 2 and the load side unit 3 are connected to each other by a refrigerant pipe 8. The heat exchanger 100 can be used in both the heat source side unit 2 and the load side unit 3. In the following, a heat exchanger 100 disposed in the heat source side unit 2 is called "heat exchanger 100A", and a heat exchanger 100 disposed in the load side unit 3 is called "heat exchanger 100B".

[0020] As shown in Fig. 3, the load side unit 3 includes the heat exchanger 100B, an air-sending device 7B, a controller 9B, and a portion of the refrigerant pipe 8. The air-sending device 7B sends air to the heat exchanger 100B. The heat exchanger 100B exchanges heat between refrigerant flowing through the heat transfer tubes 11 and air. In a case in which the refrigeration cycle apparatus 1 performs heating on the side of the load side unit 3, the heat exchanger 100B functions as a condenser, and in a case in which the refrigeration cycle apparatus 1 performs cooling on the side of the load side unit 3, the heat exchanger 100B functions as an evaporator.

[0021] The air-sending device 7B is for example a propeller fan. The air-sending device 7B is constituted by a fan motor 7a and a fan 7b. The fan 7b rotates with the fan motor 7a serving as a power source. The rotation speed of the air-sending device 7B is controlled by the controller 9B.

[0022] Further, as shown in Fig. 3, the heat source side unit 2 includes the heat exchanger 100A, a controller 9A, a compressor 4, a flow switching device 5, an expansion valve 6, an air-sending device 7A, and a portion of the refrigerant pipe 8. The heat source side unit 2 may further include other components such an accumulator.

[0023] The heat exchanger 100A exchanges heat between refrigerant flowing through the heat transfer tubes 11 and air. In a case in which the refrigeration cycle apparatus 1 performs heating on the side of the load side unit 3, the heat exchanger 100A functions as an evaporator, and in a case in which the refrigeration cycle apparatus 1 performs cooling on the side of the load side unit 3, the heat exchanger 100A functions as a condenser.

[0024] The air-sending device 7A sends air to the heat exchanger 100A. The air-sending device 7A is for example a propeller fan. As with the air-sending device 7B, the air-sending device 7A is constituted by a fan motor 7a and a fan 7b. The rotation speed of the air-sending device 7A is controlled by the controller 9A.

[0025] The compressor 4 suctions low-pressure gas refrigerant, compresses the low-pressure gas refrigerant into high-pressure gas refrigerant, and discharges the high-pressure gas refrigerant. The compressor 4 is for example an inverter compressor. The inverter compressor is enabled by the control of an inverter circuit or other circuits to change the amount of refrigerant that is sent out per unit time. The inverter circuit is mounted, for example, in the controller 9A.

[0026] The flow switching device 5 is a valve configured to switch among directions in which refrigerant in the refrigerant pipe 8 flows. The flow switching device 5 is constituted, for example, by a four-way valve. The flow switching device 5 is switched by the control of the controller 9A between a case in which the refrigeration cycle apparatus 1 performs a cooling operation and a case in which the refrigeration cycle apparatus 1 performs a heating operation. When the refrigeration cycle apparatus 1 performs cooling on the side of the load side unit 3, the flow switching device 5 is brought into a state indicated by solid lines in Fig. 3. As a result of that, the refrigerant discharged from the compressor 4 flows into the heat exchanger 100A disposed in the heat source side unit 2. On the other hand, when the refrigeration cycle apparatus 1 performs heating on the side of the load side unit 3, the flow switching device 5 is brought into a state indicated by dashed lines in Fig. 3. As a result of that, the refrigerant discharged from the compressor 4 flows into the heat exchanger 100B disposed in the load side unit 3.

[0027] The expansion valve 6 causes liquid refrigerant flowing thereinto to be decompressed by expanding action and flow out so that refrigerant liquefied in a condenser can be easily evaporated in an evaporator. Further, the expansion valve 6 adjusts the amount of refrigerant to keep the amount of refrigerant appropriate for the load on the evaporator. The expansion valve 6 is constituted, for example, by an electronic expansion valve. The opening degree of the expansion valve 6 is controlled by the controller 9A. As shown in Fig. 3, the expansion valve 6 is connected by the refrigerant pipe 8 between the heat exchanger 100A and the heat exchanger 100B.

[0028] The refrigerant pipe 8 constitutes a refrigerant circuit by connecting the compressor 4, the flow switching device 5, the heat exchanger 100A, the expansion valve 6, and the heat exchanger 100B to one another as shown in Fig. 3. The refrigerant pipe 8 is coupled to the heat transfer tubes 11 of the heat exchanger 100A and the heat transfer tubes 11 of the heat exchanger 100B.

[Configuration of Fin 12]

[0029] Fig. 4 is a partial sectional side view showing a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 4 shows the principal surface of the fin 12. Further, Fig. 4 shows cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. The heat transfer tubes 11 shown in Fig. 4 are circular tubes and are circular in cross-section. As shown in Fig. 4, the heat transfer tubes 11 are arranged in a line along the Z direction. The fin 12 has a leading edge 12a and a trailing edge 12b. Since air flows in the direction of an arrow R1 of Fig. 4, the leading edge 12a is disposed further windward than the trailing edge 12b. The heat transfer tubes 11 are inserted in through holes 12c formed in the fin 12. The outside diameter of each of the heat transfer tubes 11 is equal to the inside diameter of each of the through holes 12c. Accordingly, the heat transfer tubes 11 are in close contact with inner walls of the through holes 12c.

[0030] The principal surface of the fin 12 constitutes a fin base surface 121 that is flat. The fin base surface 121 is provided with fin projections 122. The fin projections 122 protrude in the Y direction from the fin base surface 121, which is the principal surface of the fin 12. The fin projections 122 include inner fin projections 122A provided to separately surround each of the plurality of heat transfer tubes 11. Further, the fin projections 122 include outer fin projections 122B provided to separately surround each of the inner fin projections 122A. In the following description, the inner fin projections 122A and the outer fin projections 122B are referred to simply as "fin projections 122" in a case in which there is no particular need to distinguish between them. The following description uses each of the nouns "fin projection 122", "inner fin projection 122A ", and "outer fin projection 122B" in either the singular form or the plural form.

[0031] It should be noted that although Fig. 4 uses hatching to indicate the fin projections 122 to distinguish them from the fin base surface 121, the fin projections 122 shown in Fig. 4 are not cross-sections. Fig. 4 uses solid lines to indicate visible outlines and edge lines of the fin projections 122 in a view of the fin base surface 121 in the Y direction and uses hatching to indicate portions interposed between the visible outlines and the edge lines. This applies to Figs. 8 to 13, Fig. 15, Fig. 19, Fig. 21, Fig. 23, Fig. 25, Fig. 27, Fig. 29, and Fig. 31.

[0032] As shown in Fig. 4, the fin projections 122 are circular in shape in a view of the principal surface of the fin 12 in the Y direction. The heat transfer tubes 11, the inner fin projections 122A, and the outer fin projections 122B are provided in a concentric configuration. A relationship among the diameter of each of the heat transfer tubes 11, the diameter of each of the inner fin projections 122A, and the diameter of each of the outer fin projections 122B is expressed as "Diameter of Heat Transfer Tube 11 < Diameter of Inner Fin Projection 122A < Diameter of Outer Fin Projection 122B".

[0033] The fin projections 122 are described with reference to Figs. 5 and 6. Fig. 5 is a cross-sectional view taken along line A-A in Fig. 4. Fig. 6 is a cross-sectional view taken along line B-B in Fig. 4. It should be noted that Figs. 5 and 6 omit to illustrate the heat transfer tubes. As shown in Figs. 5 and 6, the through holes 12c may have fin collars 12d at edges thereof. The fin collars 12d protrude in the Y direction from the fin base surface 121, which is the principal surface of the fin 12, along side surfaces of the heat transfer tubes 11 (see Fig. 4). Although, in Figs. 5 and 6, protruding distal ends of the fin collars 12d have bends, the protruding distal ends do not need to have bends. Protruding portions of the fin collars 12d may be linear in shape. It should be noted that although, in Figs. 5 and 6, the through holes 12c have the fin collars 12d, the through holes 12c do not need to have the fin collars 12d.

[0034] As shown in Figs. 5 and 6, there are gaps between the through holes 12c and the inner fin projections 122A. In a case in which the heat transfer tubes 11, which are inserted in the through holes 12c and protrude from the fin base surface 121, and the inner fin projections 122A are provided in contact with each other, stress concentrates on boundary portions of the heat transfer tubes 11 and the inner fin projections 122A in the formation of the fin 12. The present embodiment avoids concentration of stress in the formation of the fin 12 by providing gaps between the heat transfer tubes 11 and the inner fin projections 122A.

[0035] Further, the inner fin projections 122A and the outer fin projections 122B protrude in the same direction from the fin base surface 121 in the Y direction. There are gaps between the inner fin projections 122A and the outer fin projections 122B. These gaps between the inner fin projections 122A and the outer fin projections 122B are called "first flat portions 121A". In a case in which no first flat portions 121A are provided between the inner fin projections 122A and the outer fin projections 122B, stress concentrates on boundary portions of the inner fin projections 122A and the outer fin projections 122B in the formation of the fin. Concentration of stress in the formation of the fin is avoided by providing the first flat portions 121A.

[0036] In Figs. 5 and 6, the inner fin projections 122A and the outer fin projections 122B are triangular in cross-section. However, the inner fin projections 122A and the outer fin projections 122B do not need to be triangular in cross-section. The inner fin projections 122A and the outer fin projections 122B may for example be rectangular, polygonal, or circular in cross-section.

[0037] Next, the height of each of the inner fin projections 122A and the height of each of the outer fin projections 122B are described. Assume that h1 is the height of each of the inner fin projections 122A from the fin base surface 121 and that h2 is the height of each of the outer fin projections 122B from the fin base surface 121. Note here that the height h1 of each of the inner fin projections 122A and the height h2 of each of the outer fin projections 122B may be equal to each other as shown in Figs. 5 and 6.

[0038] A heat exchanger 100 according to the present embodiment includes a plurality of fins 12 spaced apart from one another in a first direction Y and a plurality of heat transfer tubes 11 penetrating through the plurality of fins 12, the plurality of heat transfer tubes 11 being spaced apart from one another in a second direction Z crossing the first direction Y. Each of the plurality of fins 12 includes a fin base surface 121 that is flat and a plurality of fin projections 122. The plurality of fin projections 122 include inner fin projections 122A provided to separately surround each of the plurality of heat transfer tubes 11, the inner fin projections 122A protruding in the first direction Y from the fin base surface 121, and outer fin projections 122B provided to separately surround each of the inner fin projections 122A, the outer fin projections 122B protruding in the first direction Y from the fin base surface 121.

[0039] According to this configuration, the inner fin projections 122A and the outer fin projections 122B are provided to surround the heat transfer tubes 11. For this reason, the fin projections 122 have portions extending in the second direction Z of the fin 12. That is, the provision of fin projections 122 having portions along the longitudinal direction of the fin 12 brings about improvement in longitudinal strength of the fin 12. This keeps the fin 12 from bending in the longitudinal direction when worked on, for example when pressed or when stacked. This brings about improvement in producibility of the heat exchanger.

[0040] Further, the provision of the inner fin projections 122A and the outer fin projections 122B around the heat transfer tubes 11 brings about a heat exchange promoting effect that is similar to that which is brought about in a case in which projections are provided in both the longitudinal direction and transverse direction of the fin 12. That is, regardless of whether air flows in from the longitudinal direction or transverse direction of the fin 12, the fin projections 122 are provided in the direction of flow of air. This makes it possible to effectively utilize the inner fin projections 122A and the outer fin projections 122B as heat transfer elements. This results in improvement in heat transfer coefficient on the surface of the fin 12, bringing about improvement in heat transfer performance of the heat exchanger.

[0041] Further, in the fin 12 according to the present embodiment, the inner fin projections 122A and the outer fin projections 122B are provided around through holes 12c in which the heat transfer tubes 11 are inserted. In the formation of the fin projections 122, the material is stretched in a well-balanced manner from all parts of the fin 12, so that distortions in shape due to concentration of stress on the fin base surface 121 can be reduced. This brings about improvement in workability of the fin 12, bringing about improvement in manufacturability of the heat exchanger.

[0042] Further, in the heat exchanger 100 according to the present embodiment, the plurality of heat transfer tubes 11 are circular in cross-section, and each of the inner fin projections 122A and a corresponding one of the outer fin projections 122B are provided concentrically with a corresponding one of the plurality of heat transfer tubes 11. In this configuration, the inner fin projection 122A and the outer fin projection 122B are provided along a circumferential direction of a circular cross-section of the heat transfer tube 11. In the formation of the inner fin projection 122A and the outer fin projection 122B, the fin is deformed uniformly in the circumferential direction of the cross-section of the heat transfer tube 11, so that it is hard for stress to concentrate. This brings about improvement in formability of the fin 12, resulting in improvement in manufacturability of the heat exchanger.

[0043] Further, in the heat exchanger 100 according to the present embodiment, the fin base surface 121 has first flat portions 121A between the inner fin projections 122A and the outer fin projections 122B. In this configuration, the first flat portions 121A allows the inner fin projections 122A and the outer fin projections 122B to be provided on the fin 12 without touching each other. This makes it hard for stress to concentrate between the inner fin projections 122A and the outer fin projections 122B in the formation of the fin. This brings about improvement in formability of the fin 12, resulting in improvement in manufacturability of the heat exchanger.

[Modification 1 of Embodiment 1]

[0044] Fig. 7 is a cross-sectional view showing Modification 1 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 7 shows a portion of Modification 1 that corresponds to a cross-section taken along line B-B in Fig. 4. In Modification 1 shown in Fig. 7 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B.

[0045] The heat exchanger 100 according to Modification 1 is different from Embodiment 1 in relationship between the height h1 of each of the inner fin projections 122A from the fin base surface 121 and the height h2 of each of the outer fin projections 122B from the fin base surface 121. In Embodiment 1 shown in Figs. 5 and 6, the height h1 of each of the inner fin projections 122A and the height h2 of each of the outer fin projections 122B are equal to each other. Meanwhile, in Modification 1, as shown in Fig. 7, the height h1 of each of the inner fin projections 122A is greater than the height h2 of each of the outer fin projections 122B. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0046] In the heat exchanger 100 according to Embodiment 1 or Modification 1 of Embodiment 1, a relationship between the height h1 of each of the inner fin projections 122A and the height h2 of each of the outer fin projections 122B is expressed as $h2 \leq h1$. A portion of air colliding with the outer fin projection 122B flows along a slope of the outer fin projection 122B toward an apex of the outer fin projection 122B and passes through the highest part of the outer fin projection 122B. If the height h2 of the outer fin projection 122B is higher than the height h1 of the inner fin projection 122A, air passing through the highest part of the outer fin projection 122B flows into a space above the highest part of the inner fin projection 122A, that is, a space in which the inner fin projection 122A is not present. Therefore, a portion of air colliding with the outer fin projection 122B does not collide with the inner fin projection 122A. Meanwhile, in a case in which the height h2 of the outer fin projection 122B and the height h1 of the inner fin projection 122A are equal to each other, it is easy for air colliding with the outer fin projection 122B to collide with the inner fin projection 122A. This allows more air to flow into the space between the outer fin projection 122B and the inner fin projection 122A. Furthermore, in a case in which the height h2 of the outer fin projection 122B is lower than the height h1 of the inner fin projection 122A, air passing beyond the highest part of the outer fin projection 122B collides with the inner fin projection 122A. This allows more air to flow into the space between the outer fin projection 122B and the inner fin projection 122A. Further, air colliding with the inner fin projection 122A also easily flows into a gap between the inner fin projection 122A and the heat transfer tube 11. Accordingly, in the configuration of Embodiment 1 or Modification 1, in which the relationship between the height h1 of the inner fin projection 122A and the height h2 of the outer fin projection 122B is expressed as $h2 \leq h1$, more air flows into the gap between the outer fin projection 122B and the inner fin projection 122A and the gap between the inner fin projection 122A and the heat transfer tube 11. This increases the area of contact of air with the outer fin projection 122B and the inner fin projection 122A, bringing about improvement in heat transfer coefficient on the surface of the fin 12 and improvement in heat transfer performance of the heat exchanger.

[Modification 2 of Embodiment 1]

[0047] Fig. 8 is a partial sectional side view showing Modification 2 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 8 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 2 shown in Fig. 8 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B.

[0048] As shown in Fig. 8, the inner fin projections 122A and the outer fin projections 122B in Modification 2 of Embodiment 1 are provided in rectangular shapes to surround the heat transfer tubes 11. Differences from Embodiment 1 lie in the shapes of the inner fin projections 122A and the outer fin projections 122B. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0049] In Modification 2, since the inner fin projections 122A and the outer fin projections 122B are rectangular, the fin projections 122 have portions linearly extending in the Z direction of the fin 12. That is, the provision of fin projections 122 having linear portions along the longitudinal direction of the fin 12 brings about further improvement in longitudinal strength of the fin 12. As in the case of Embodiment 1, this keeps the fin 12 from bending in the longitudinal direction when worked on, for example when pressed or when stacked. This brings about improvement in producibility of the heat exchanger.

[Modification 3 of Embodiment 1]

[0050] Fig. 9 is a partial sectional side view showing Modification 3 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 9 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 3 shown in Fig. 9 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B.

[0051] As shown in Fig. 9, the inner fin projections 122A and the outer fin projections 122B in Modification 3 of Embodiment 1 are provided in elliptical shapes to surround the heat transfer tubes 11. Differences from Embodiment 1 lie in the shapes of the inner fin projections 122A and the outer fin projections 122B. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0052] As shown in Fig. 9, the inner fin projections 122A and the outer fin projections 122B are larger in diameter in the X direction than in the Z direction. That is, the fin projections 122 have portions elongated in the transverse direction of the fin 12, that is, the direction in which air flows in. This makes it easy for air to make contact with the fin projections 122. As in the case of Embodiment 1, this results in improvement in heat transfer coefficient on the surface of the fin 12.

[Modification 4 of Embodiment 1]

[0053] Fig. 10 is a cross-sectional view showing Modification 4 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 10 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 4 shown in Fig. 10 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B.

[0054] As shown in Fig. 10, in Modification 4 of Embodiment 4, the inner fin projections 122A and the outer fin projections 122B are different in shape from each other. As with the inner fin projections 122A in Embodiment 1, each of the inner fin projections 122A in Modification 4 is provided concentrically with a corresponding one of the heat transfer tubes 11. Meanwhile, the outer fin projections 122B in Modification 4 are provided in elliptical shapes to surround the heat transfer tubes 11. Differences from Embodiment 1 lie in the shapes of the outer fin projections 122B. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0055] In Modification 4, the inner fin projections 122A are in the shapes of circles provided concentrically with the heat transfer tubes 11. Meanwhile, the outer fin projections 122B are in the shapes of ellipses. As shown in Fig. 10, the outer fin projections 122B are larger in diameter in the X direction than in the Z direction. That is, the outer fin projections 122B have portions elongated in the transverse direction of the fin 12, that is, the direction in which air flows in. This makes it easy for air to make contact with the fin projections 122. As in the case of Embodiment 1, this results in improvement in heat transfer coefficient on the surface of the fin 12.

[Modification 5 of Embodiment 1]

[0056] Fig. 11 is a cross-sectional view showing Modification 5 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 11 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 5 shown in Fig. 11 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B.

[0057] As shown in Fig. 11, in Modification 5 of Embodiment 1, additional fin projections 122D are provided to surround the outer fin projections 122B. Differences between Embodiment 1 and Modification 5 lie in these additional fin projections 122D. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0058] In Modification 5, one or more additional fin projections 122D are provided concentrically with the heat transfer tubes 11 to surround the outer fin projections 122B. For this reason, the fin projections 122 have portions elongated in the second direction Z of the fin 12. That is, the provision of fin projections 122 having portions along the longitudinal direction of the fin 12 brings about improvement in longitudinal strength of the fin 12. This keeps the fin from bending in the longitudinal direction when worked on, for example when pressed or when stacked. This brings about improvement in producibility of the heat exchanger.

[0059] Further, the provision of the additional fin projections 122D around the outer fin projections 122B brings about an effect that is similar to that which is brought about in a case in which projections are added in both the longitudinal direction and transverse direction of the fin 12. That is, regardless of whether air flows in from the longitudinal direction or transverse direction of the fin 12, projections are added in the direction of flow of air. This makes it possible to effectively utilize the additional fin projections 122D as heat transfer elements. Further, this makes it easier for inflow air to make contact with the additional fin projections 122D, thus bringing about improvement in heat transfer coefficient and improvement in heat transfer performance of the heat exchanger.

[Modification 6 of Embodiment 1]

[0060] Fig. 12 is a partial sectional side view showing Modification 6 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 12 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 6 shown in Fig. 12 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B.

[0061] As shown in Fig. 12, in Modification 6 of Embodiment 1, the heat transfer tubes 11 are constituted by flat tubes. Further, the inner fin projections 122A and the outer fin projections 122B are provided in rectangular shapes to surround the heat transfer tubes 11. Differences between Embodiment 1 and Modification 6 lie in the shapes of the heat transfer tubes 11, the inner fin projections 122A, and the outer fin projections 122B. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0062] In Modification 6, since the inner fin projections 122A and the outer fin projections 122B are rectangular, the fin projections 122 have portions linearly extending in the Z direction of the fin 12. That is, the provision of fin projections 122 having linear portions along the longitudinal direction of the fin 12 brings about further improvement in longitudinal strength of the fin 12. As in the case of Embodiment 1, this keeps the fin from bending in the longitudinal direction when worked on, for example when pressed or when stacked. This brings about improvement in producibility of the heat exchanger.

[Modification 7 of Embodiment 1]

[0063] Fig. 13 is a partial sectional side view showing Modification 7 of a fin 12 of the heat exchanger 100 according to Embodiment 1. Fig. 13 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 7 shown in Fig. 13 too, as in the case of Embodiment 1, the fin projections 122 include inner fin projections 122A and outer fin projections 122B. Fig. 14 is a cross-sectional view taken along line A-A in Fig. 13.

[0064] As shown in Figs. 13 and 14, in Modification 7 of Embodiment 1, no first flat portions 121A are provided between the inner fin projections 122A and the outer fin projections 122B. This is a point of difference from Embodiment 1. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0065] In Modification 7, the fin base surface 121 has no first flat portions 121A. This makes it impossible to bring about an effect of avoiding concentration of stress between the inner fin projections 122A and the outer fin projections 122B in the formation of the fin. However, in terms of improvement in longitudinal strength of the fin 12 and improvement in heat transfer coefficient of the surface of the fin 12, Modification 7 brings about an effect that is similar to that of Embodiment 1.

[0066] In Embodiment 1 and Modifications 1 to 7 thereof, the shapes of the inner fin projections 122A and the outer fin projections 122B are described with reference to Fig. 4 and Figs. 8 to 14. In each of Fig. 4 and Figs. 8 to 14, the plurality of heat transfer tubes 11 are surrounded by inner fin projections 122A of the same shape. However, inner fin projections 122A having different shapes may be provided separately for each of the heat transfer tubes 11. Further, in each of Fig. 4 and Figs. 8 to 14, the plurality of inner fin projections 122A are surrounded by outer fin projections 122B of the same shape. However, outer fin projections 122B having different shapes may be provided separately for each of the heat transfer tubes 11.

Embodiment 2.

[0067] The following describes a heat exchanger 100 and a refrigeration cycle apparatus 1 according to Embodiment 2.

[Basic Configuration of Heat Exchanger 100]

[0068] A basic configuration of a heat exchanger 100 according to Embodiment 2 is not described here, as it is the same as that of the heat exchanger 100 of Embodiment 1.

[Basic Configuration of Refrigeration Cycle Apparatus 1]

[0069] A basic configuration of a refrigeration cycle apparatus 1 according to Embodiment 2 is not described here, as it is the same as that of the refrigeration cycle apparatus 1 of Embodiment 1.

[Configuration of Fin 12]

[0070] Fig. 15 is a partial sectional side view showing a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 15 shows the principal surface of the fin 12 and cross-sections of heat transfer tubes 11. The cross-sections of the heat transfer tubes 11 shown in Fig. 15 are cross-sections parallel to the principal surface of the fin 12. As shown in Fig. 15, the heat transfer tubes 11 are arranged in a line along a column-wise direction parallel with the longitudinal direction of the fin 12. The fin 12 has a leading edge 12a and a trailing edge 12b. In the following, the upper heat transfer tube 11 as seen from the front of the surface of paper of Fig. 15 is called "first heat transfer tube 11A", and the lower heat transfer tube 11 as seen from the front of the surface of paper of Fig. 15 is called "second heat transfer tube 11B".

[0071] As in the case of Embodiment 1, the principal surface of the fin 12 constitutes a fin base surface 121 that is flat. Further, as in the case of Embodiment 1, the inner fin projections 122A and the outer fin projections 122B are provided to protrude in the Y direction from the fin base surface 121. In Embodiment 2, an inner fin projection 122A provided to surround the first heat transfer tube 11A is called "first inner fin projection 122A-1". Further, an outer fin projection 122B provided to surround the first inner fin projection 122A-1 is called "first outer fin projection 122B-1". Furthermore, in Embodiment 2, an inner fin projection 122A provided to surround the second heat transfer tube 11B is called "second inner fin projection 122A-2". Further, an outer fin projection 122B provided to surround the second inner fin projection 122A-2 is called "second outer fin projection 122B-2".

[0072] The fin 12 in Embodiment 2 is described with reference to Figs. 15 to 17. Fig. 16 is a cross-sectional view taken along line A-A in Fig. 15. Fig. 17 is a cross-sectional view taken along line C-C in Fig. 15. In the following description, the first inner fin projection 122A-1 and the second inner fin projection 122A-2 are referred to simply as "inner fin projections 122A" in a case in which there is no particular need to distinguish between them. Further, the first outer fin projection 122B-1 and the second outer fin projection 122B-2 are referred to simply as "outer fin projections 122B" in a case in which there is no particular need to distinguish between them.

[0073] There is a gap between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. A portion of the gap between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 surrounded by thick dot-and-dash lines in Fig. 15 is called "second flat portion 121B". That is, when viewed from the front of the surface of paper of Fig. 15, the second flat portion 121B is a portion of the fin base surface 121 interposed between a lower semicircular portion of the first outer fin projection 122B-1 and an upper semicircular portion of the second outer fin projection 122B-2. Further, in Fig. 16, a linear portion between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 corresponds to the second flat portion 121 B. In a case in which no second flat portion 121B is provided between the first outer fin projection 122B-1 and the second outer fin projection 122B-2, stress concentrates on boundary portions of the first outer fin projection 122B-1 and the second outer fin projection 122B-2 in the formation of the fin. Concentration of stress in the formation of the fin is avoided by providing the second flat portion 121B.

[0074] As shown in Fig. 15, the fin base surface 121 is provided with intermediate fin projections 122C. As shown in Fig. 17, the intermediate fin projections 122C protrude in the Y direction from the portion of the fin base surface 121 situated between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. That is, in Embodiment 2, the fin projections 122 include the inner fin projections 122A, the outer fin projections 122B, and the intermediate fin projections 122C. As shown in Figs. 16 and 17, the inner fin projections 122A, the outer fin projections 122B, and the intermediate fin projections 122C protrude in the same direction from the fin base surface 121 in the Y direction. A basic configuration of the fin 12 according to Embodiment 2 is not described, as it is identical to that of Embodiment 1 except for the intermediate fin projections 122C. It should be noted that the number of intermediate fin projections 122C is not limited to 2, although two intermediate fin projections 122C are provided in Fig. 15. One intermediate fin projection 122C may be provided, or three or more intermediate fin projections 122C may be provided.

[0075] The intermediate fin projections 122C are provided in a space between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 in the longitudinal direction of the fin 12. However, the intermediate fin projections 122C do not need to be wholly located in the space between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. As shown in Fig. 15, the intermediate fin projections 122C need only be partially located in the space between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. In the present disclosure, the space between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 refers to the portion of the fin base surface 121 that corresponds to the second flat portion 121B.

[0076] Further, in the present disclosure, a straight line passing through the center of the first heat transfer tube 11A and the center of the second heat transfer tube 11B along the Z direction is called "center line CL". In Fig. 15, a dot-and-dash line indicating the A-A cross-section corresponds to the center line CL. The intermediate fin projections 122C are provided at positions not crossing the center line CL.

[0077] Next, the shapes of the intermediate fin projections 122C are described with reference to Fig. 15. Each of the intermediate fin projections 122C includes a first raised portion 122c-1 and a second raised portion 122c-2 that rise from the fin base surface 121. The first raised portion 122c-1 and the second raised portion 122c-2 extend parallel along the Z direction of the fin 12. The first raised portion 122c-1 is greater in length than the second raised portion 122c-2. Further, in the X direction, the distance between the first raised portion 122c-1 and the center line CL is longer than the distance between the second raised portion 122c-2 and the center line CL.

[0078] The first raised portion 122c-1 has two ends in the Z direction. One of the two ends of the first raised portion 122c-1 that is close to the first outer fin projection 122B-1 is called "first end 122c-1a". Further, one of the two ends of the first raised portion 122c-1that is close to the second outer fin projection 122B-2 is called "second end 122c-1b". That is, the first raised portion 122c-1 has the first end 122c-1a and the second end 122c-1b. Further, the second raised portion 122c-2 has two ends in the Z direction. One of the two ends of the second raised portion 122c-2 that is close to the first outer fin projection 122B-1 is called "first end 122c-2a". Further, one of the two ends of the second raised portion 122c-2 that is close to the second outer fin projection 122B-2 is called "second end 122c-2b". That is, the second raised portion 122c-2 has the first end 122c-2a and the second end 122c-2b.

[0079] Next, a positional relationship between each of the intermediate fin projections 122C and the outer fin projections 122B is described with reference to a first virtual line VL1 and a second virtual line VL2 that are indicated by dashed lines in Fig. 15. In the present disclosure, the first virtual line VL1 is a virtual straight line passing through the first end 122c-1a of the first raised portion 122c-1 and the first end 122c-2a of the second raised portion 122c-2. Further, the second virtual line VL2 is herein a virtual straight line passing through the second end 122c-1b of the first raised portion 122c-1 and the second end 122c-2b of the second raised portion 122c-2. As shown in Fig. 15, the first virtual line VL1 does not cross the first outer fin projection 122B-1. Therefore, a given gap is formed between a portion of the intermediate fin projection 122C connecting the first end 122c-1a of the first raised portion 122c-1 with the first end 122c-2a of the second raised portion 122c-2 and the first outer fin projection 122B-1. Further, the second virtual line VL2 does not cross the second outer fin projection 122B-2. Therefore, a given gap is formed between a portion of the intermediate fin projection 122C connecting the second end 122c-1b of the first raised portion 122c-1 with the second end 122-2b of the second raised portion 122c-2 and the second outer fin projection 122B-2. The given gaps here are portions of the fin base surface 121 and flat regions having areas for avoiding concentration of stress around the intermediate fin projection 122C in the formation of the fin. If the areas of the gaps between the intermediate fin projection 122C and the outer fin projections 122B are small, concentration of stress around the intermediate fin projection 122C in the formation of the fin cannot be avoided. The intermediate fin projection 122C is provided so that the first virtual line VL1 does not cross the first outer fin projection 122B-1. This makes it possible to secure a flat region on the fin base surface 121 between the intermediate fin projection 122C and the first outer fin projection 122B-1 that can avoid concentration of stress in the formation of the fin. Further, the intermediate fin projection 122C is provided so that the second virtual line VL2 does not cross the second outer fin projection 122B-2. This makes it possible to secure a flat region on the fin base surface 121 between the intermediate fin projection 122C and the second outer fin projection 122B-2 that can avoid concentration of stress in the formation of the fin.

[0080] In the heat exchanger 100 according to the present embodiment, the plurality of heat transfer tubes 11 include a first heat transfer tube 11A and a second heat transfer tube 11B that are adjacent to each other in the second direction Z. The inner fin projections 122A include a first inner fin projection 122A-1 provided to surround the first heat transfer tube 11A and a second inner fin projection 122A-2 provided to surround the second heat transfer tube 11B. Further, the outer fin projections 122B include a first outer fin projection 122B-1 provided to surround the first inner fin projection 122A-1 and a second outer fin projection 122B-2 provided to surround the second inner fin projection 122A-2. Moreover, the fin base surface 121 has a second flat portion 121B between the first outer fin projection 122B-1 and the second outer fin projection 122B-2.

[0081] According to this configuration, the second flat portion 121B allows the first outer fin projections 122B-1 and the second outer fin projection 122B-2 to be provided on the fin 12 without touching each other. This prevents stress from concentrating between the first outer fin projections 122B-1 and the second outer fin projection 122B-2 in the formation of the fin. This brings about improvement in formability of the fin 12, resulting in improvement in manufacturability of the heat exchanger.

[0082] Further, in the heat exchanger 100 according to the present embodiment, the plurality of fin projections 122 include an intermediate fin projection 122C protruding in the first direction Y from the fin base surface 121, and the intermediate fin projection 122C is provided so that at least part of the intermediate fin projection 122C is located between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 in the second direction Z.

[0083] According to this configuration, providing the intermediate fin projection 122C makes it easy for air to make contact with the surface of the fin 12. This results in further improvement in heat transfer coefficient on the surface of the fin 12. Further, locating part of the intermediate fin projection 122C between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 results in reducing a region in which no fin projections 122 are present in the longitudinal direction of the fin 12. This brings about further improvement in longitudinal strength of the fin 12.

[0084] Further, in the heat exchanger 100 according to the present embodiment, the intermediate fin projection 122C is provided at a position not crossing a center line CL passing through a center of the first heat transfer tube 11A and a center of the second heat transfer tube 11B along the second direction Z. Note here that in the second direction Z of the fin 12, a length between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 is shortest in a portion through which the center line CL passes. In the present embodiment, the intermediate fin projection 122C is provided not at a position where the first outer fin projection 122B-1 and the second outer fin projection 122B-2 are closest to each other but at a place where there is a relatively large gap between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. By thus reducing a flat surface of the fin base surface 121 by providing an intermediate fin projection 122C extending along the longitudinal direction of the fin 12, improvement in longitudinal strength of the fin 12 can be brought about. Further, a long portion of the intermediate fin projection 122C makes it easy for air to make contact with the surface of the fin 12, bringing about further improvement in heat transfer coefficient.

[0085] Further, in the heat exchanger 100 according to the present embodiment, assuming that a transverse direction of the plurality of fins 12 is a third direction X crossing the first direction Y and the second direction Z, the intermediate fin projection 122C includes a first raised portion 122c-1 extending in the second direction Z, the first raised portion 122c-1 being raised from the fin base surface 121, and a second raised portion 122c-2 extending parallel to the first raised portion 122c-1, the second raised portion 122c-2 raised from the fin base surface 121. In the second direction Z, the first raised portion 122c-1 is greater in length than the second raised portion 122c-2. In the third direction X, a distance between the first raised portion 122c-1 and the center line CL is longer than a distance between the second raised portion 122c-2 and the center line CL. Further, in the second direction Z, the first raised portion 122c-1 includes a first end 122c-1a provided adjacent to the first outer fin projection 122B-1 and a second end 122c-1b provided adjacent to the second outer fin projection 122B-2. Further, in the second direction Z, the second raised portion 122c-2 includes a first end 122c-2a provided adjacent to the first outer fin projection 122B-1 and a second end 122c-2b provided adjacent to the second outer fin projection 122B-2. A first virtual line VL1 passing through the first end 122c-1a of the first raised portion 122c-1 and the first end 122c-2a of the second raised portion 122c-2 does not cross the first outer fin projection 122B-1. Further, a second virtual line VL2 passing through the second end 122c-1b of the first raised portion 122c-1 and the second end 122c-2b of the second raised portion 122c-2 does not cross the second outer fin projection 122B-2.

[0086] This configuration makes it possible to secure flat regions on the fin base surface 121 between the intermediate fin projection 122C and the outer fin projections 122B for avoiding concentration of stress between the intermediate fin projection 122C and the outer fin projections 122B in the formation of the fin. This brings about further improvement in formability of the fin 12.

[Modification 1 of Embodiment 2]

[0087] Fig. 18 is a cross-sectional view showing Modification 1 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 18 shows a portion of Modification 1 that corresponds to a cross-section taken along line C-C in Fig. 15. In Modification 1 shown in Fig. 18 too, as in the case of Embodiment 2, the fin 12 includes intermediate fin projections 122C.

[0088] In the heat exchanger 100 according to Modification 1 of Embodiment 2, in the Y direction, a direction in which the inner fin projections 122A protrude from the fin base surface 121 and a direction in which the outer fin projections 122B protrude from the fin base surface 121 are identical to each other. Meanwhile, in the Y direction, the intermediate fin projection 122C protrudes in a direction opposite to the direction in which the inner fin projections 122A and the outer fin projections 122B protrude. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0089] In the heat exchanger 100 according to Modification 1 of Embodiment 2, in the first direction Y, a direction in which the inner fin projections 122A protrude from the fin base surface 121 and a direction in which the intermediate fin projection 122C protrudes from the fin base surface 121 are opposite to each other. Accordingly, the inner fin projections 122A are not located in a wake flow portion of the intermediate fin projection 122C. That is, the inner fin projections 122A are not affected by a dead water region of the intermediate fin projection 122C. This can result in maximized utilization of the inner fin projections 122A for heat exchange, bringing about improvement in heat transfer coefficient on the surface of the fin 12.

[0090] Further, in the first direction Y, a direction in which the outer fin projections 122B protrude from the fin base surface 121 is identical to a direction in which the inner fin projections 122A protrude. That is, the outer fin projections 122B too are not located in a wake flow portion of the intermediate fin projection 122C and are therefore not affected by a dead water region of the intermediate fin projection 122C. This can result in maximized utilization of the outer fin projections 122B for heat exchange, bringing about further improvement in heat transfer coefficient on the surface of the fin 12.

[0091] Further, in Modification 1, the center of gravity of the fin 12 is close to the fin base surface 121 in the Y direction, as the inner fin projections 122A and the intermediate fin projection 122C protrude in directions opposite to each other. This brings about improvement in strength of the fin 12.

[Modification 2 of Embodiment 2]

[0092] Fig. 19 is a partial sectional side view showing Modification 2 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 19 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 2 shown in Fig. 19 too, as in the case of Embodiment 2, the fin projections 122 include an intermediate fin projection 122C. Fig. 20 is a cross-sectional view taken along line A-A in Fig. 19.

[0093] As shown in Figs. 19 and 20, in Modification 2 of Embodiment 2, the intermediate fin projection 122C is provided between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 to overlap the center line CL. As shown in Fig. 19, in Modification 2, when viewed from the Y direction, the intermediate fin projection 122C has the shape of an oblong whose long sides extend in the Z direction. Differences between Modification 2 and Embodiment 2 lie in the position of the intermediate fin projection 122C and the shape of the intermediate fin projection 122C. Other components and workings are not described here, as they are the same as those of Embodiment 1.

[0094] In Modification 2, the intermediate fin projection 122C overlaps the center line CL between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. The distance between the first raised portion 122c-1 and the center line CL and the distance between the second raised portion 122c-2 and the center line CL are equal to each other. Further, the first raised portion 122c-1 and the second raised portion 122c-2 are equal in length to each other. In Fig. 19, the first raised portion 122c-1 is the left long side as seen from the front of the surface of paper, and the second raised portion 122c-2 is the right long side as seen from the front of the surface of paper.

[0095] In Modification 2, the intermediate fin projection 122c is located in a portion in which the distance between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 is shortest in the Z direction. In a case in which the distance between adjacent heat transfer tubes 11 are relatively long, providing an intermediate fin projection 122C as in the case of Modification 2 brings about improvement in longitudinal strength of the fin 12 and improvement in heat transfer coefficient of the surface of the fin 12.

[Modification 3 of Embodiment 2]

[0096] Fig. 21 is a partial sectional side view showing Modification 3 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 21 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 3 shown in Fig. 21 too, as in the case of Embodiment 2, the fin projections 122 include an intermediate fin projection 122C. Fig. 22 is a cross-sectional view taken along line A-A in Fig. 21.

[0097] As shown in Figs. 21 and 22, in Modification 3 of Embodiment 2, the intermediate fin projection 122C is provided between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 to cross the center line CL. The intermediate fin projection 122C has a portion elongated in the X direction. In Fig. 21, in the X direction, the intermediate fin projection 122C is larger in diameter than the first outer fin projection 122B-1 and the second outer fin projection 122B-2. However, in the X direction, the intermediate fin projection 122C may be larger in diameter than or equal in diameter to the first outer fin projection 122B-1 and the second outer fin projection 122B-2. Differences between Modification 3 and Embodiment 2 lie in that the intermediate fin projection 122C is provided to cross the center line CL and in the shape of the intermediate fin projection 122C. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0098] In Modification 3, an intermediate fin projection 122C extending along the X direction, which is the transverse direction of the fin 12, is provided between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 to cross the center line CL. Further, portions of the first and second raised portions 122c-1 and 122c-2 that extend along the Z direction, which is the longitudinal direction of the fin 12, are shorter than portions of the first and second raised portions 122c-1 and 122c-2 that extend along the X direction. That is, in Modification 3, the intermediate fin projection 122C, unlike the intermediate fin projections 122C in Embodiment 2, does not have a portion elongated along the longitudinal direction of the fin 12. However, in Modification 3 too, providing the intermediate fin projection 122C brings about improvement in longitudinal strength of the fin 12. Further, in Modification 3, the intermediate fin projection 122C makes it easy for air to make contact with the surface of the fin 12, as the intermediate fin projection 122C has a portion elongated in the X direction, in which air flows in. This brings about improvement in heat transfer coefficient on the surface of the fin 12.

[Modification 4 of Embodiment 2]

[0099] Fig. 23 is a partial sectional side view showing Modification 4 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 23 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 4 shown in Fig. 23 too, as in the case of Embodiment 2, the fin projections 122 include an intermediate fin projection 122C. Fig. 24 is a cross-sectional view taken along line A-A in Fig. 23.

[0100] As shown in Figs. 23 and 24, in Modification 4 of Embodiment 2, the intermediate fin projection 122C is provided between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 to overlap the center line CL. As shown in Fig. 23, in Modification 4, when viewed from the Y direction, the intermediate fin projection 122C has a circular shape. As shown Fig. 24, the intermediate fin projection 122C protrudes in a semispherical shape from the fin base surface 121. Differences between Modification 4 and Embodiment 2 lie in the position of the intermediate fin projection 122C and the shape of the intermediate fin projection 122C. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0101] In Modification 4, the intermediate fin projection 122C overlaps the center line CL between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. A portion of the intermediate fin projection 122C in Modification 4 elongated along the longitudinal direction of the fin 12 is not as long as portions of the intermediate fin projections 122C in Embodiment 2 elongated along the longitudinal direction of the fin 12. However, in Modification 4 too, providing the intermediate fin projection 122C brings about improvement in longitudinal strength of the fin 12 and improvement in heat transfer coefficient of the surface of the fin 12.

[Modification 5 of Embodiment 2]

[0102] Fig. 25 is a partial sectional side view showing Modification 5 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 25 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 5 shown in Fig. 25 too, as in the case of Embodiment 2, the fin projections 122 include intermediate fin projections 122C. Fig. 26 is a cross-sectional view taken along line C-C in Fig. 25.

[0103] As shown in Fig. 25, in Modification 5 of Embodiment 2, each of the intermediate fin projections 122C is configured such that the first raised portion 122c-1 and the second raised portion 122c-2 are equal in length to each other. In the aforementioned Embodiment 2, as shown in Fig. 15, a case has been described in which the first raised portion 122c-1 is greater in length than the second raised portion 122c-2. Differences between Modification 5 and Embodiment 2 lie in a relationship in length between the first raised portion 122c-1 and the second raised portion 122c-2. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0104] In Modification 5, the first virtual line VL1 crosses the first outer fin projection 122B-1. Further, the second virtual line VL2 crosses the second outer fin projection 122B-2. In a case in which the distance between the first outer fin projection 122B-1 and the second outer fin projection 122B-2 is secured in the Z direction, intermediate fin projections 122C shaped as shown in Modification 5 may be provided. Providing the intermediate fin projections 122C of Modification 5 brings about improvement in longitudinal strength of the fin 12 and improvement in heat transfer coefficient of the surface of the fin 12.

[Modification 6 of Embodiment 2]

[0105] Fig. 27 is a partial sectional side view showing Modification 6 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 27 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 6 shown in Fig. 27 too, as in the case of Embodiment 2, the fin projections 122 include intermediate fin projections 122C. Fig. 28 is a cross-sectional view taken along line C-C in Fig. 27.

[0106] As shown in Fig. 27, in Modification 6 of Embodiment 2, when viewed from Y direction, the intermediate fin projections 122C have T shapes laid down 90 degrees. Therefore, as shown in Fig. 28, the intermediate fin projections 122C have portions elongated in the X direction. Differences between Modification 6 and Embodiment 2 lie in the shapes of the intermediate fin projections 122C. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0107] In Modification 6, the first virtual line VL1 crosses the first outer fin projection 122B-1. Further, the second virtual line VL2 crosses the second outer fin projection 122B-2. Furthermore, portions of the intermediate fin projections 122C elongated in the X direction are located between the first outer fin projection 122B-1 and the second outer fin projection 122B-2. Each of the intermediate fin projections 12C of Modification 6 includes a portion linearly extending along the longitudinal direction (Z direction) of the fin 12 and a portion linearly extending along the transverse direction (X direction). Providing the intermediate fin projections 122C of Modification 6 brings about longitudinal strength of the fin 12. Furthermore, the intermediate fin projections 122C make it easy for air to make contact with the surface of the fin 12, as the intermediate fin projections 122C have portions elongated in the X direction, in which air flows in. Therefore, Modification 6 can bring about further improvement in heat transfer coefficient on the surface of the fin 12 than Embodiment 2.

[Modification 7 of Embodiment 2]

[0108] Fig. 29 is a partial sectional side view showing Modification 7 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 29 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 7 shown in Fig. 29 too, as in the case of Embodiment 2, the fin projections 122 include intermediate fin projections 122C. Fig. 30 is a cross-sectional view taken along line C-C in Fig. 29.

[0109] As shown in Fig. 29, in Modification 7 of Embodiment 2, the intermediate fin projections 122C include first intermediate fin projections 122C-1 and second intermediate fin projections 122C-2. The first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 have the shapes of oblongs whose long sides extend in the Z direction when viewed from the Y direction. Differences between Modification 7 and Embodiment 2 lie in that in Modification 7, the intermediate fin projections 122C include the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2. Further, the shapes of the intermediate fin projections 122C in Embodiment 2 and the shapes of the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 in Modification 7 are different from each other. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0110] In the following description, the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 are referred to simply as "intermediate fin projections 122C" in a case in which there is no particular need to distinguish between them. The following description uses the noun "intermediate fin projection 122C" in either the singular form or the plural form. Further, as for the first raised portions 122c-1 too, the first raised portions 122c1-1 of the first intermediate fin projections 122C-1 and the first raised portions 122c2-1 of the second intermediate fin projections 122C-2 are referred to simply as "first raised portions 122c-1" in a case in which there is no particular need to distinguish between them. Furthermore, as for the second raised portions 122c-2 too, the second raised portions 122c1-2 of the first intermediate fin projections 122C-1 and the first raised portions 122c2-2 of the second intermediate fin projections 122C-2 are referred to simply as "second raised portions 122c-2" in a case in which there is no particular need to distinguish between them. The following description uses each of the nouns "first raised portion 122c-1" and "second raised portion 122c-2" in either the singular form or the plural form.

[0111] The first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 are described with reference to Fig. 29. Each of the first intermediate fin projections 122C-1 is configured such that the first raised portion 122c1-1 and the second raised portion 122c1-2 are equal in length to each other. Further, each of the second intermediate fin projections 122C-2 is configured such that the first raised portion 122c2-1 and the second raised portion 122c2-2 are equal in length to each other. It should be noted that differences between the intermediate fin projections 122C in Embodiment 2 and the intermediate fin projections 122C in Modification 7 lie in relationships in length between the first raised portions 122c-1 and the second raised portions 122c-2.

[0112] Further, the number of first intermediate fin projections 122C-1 is not limited to 2, although two first intermediate fin projections 122C-1 are provided in Fig. 29. One first intermediate fin projection 122C-1 may be provided, or three or more first intermediate fin projections 122C-1 may be provided. Further, the number of second intermediate fin projections 122C-2 is not limited to 2, although two second intermediate fin projections 122C-2 are provided in Fig. 29. One second intermediate fin projection 122C-2 may be provided, or three or more second intermediate fin projections 122C-2 may be provided.

[0113] Further, the distance between each of the first intermediate fin projections 122C-1 and the center line CL is longer than the distance between each of the second intermediate fin projections 122C-2 and the center line CL. Further, the first raised portions 122c1-1 of the first intermediate fin projections 122C-1 are greater in length than the first raised portions 122c2-1 of the second intermediate fin projections 122C-2. That is, the first intermediate fin projections 122C-1 are larger than the second intermediate fin projections 122C-2.

[0114] As mentioned above, in Modification 7, the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2, which linearly extend along the longitudinal direction of the fin 12, are arranged along the transverse direction of the fin. In Modification 7, providing the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 brings about improvement in longitudinal strength of the fin 12 and improvement in heat transfer coefficient of the surface of the fin 12.

[Modification 8 of Embodiment 2]

[0115] Fig. 31 is a partial sectional side view showing Modification 8 of a fin 12 of the heat exchanger 100 according to Embodiment 2. Fig. 31 shows the surface of the fin 12 and cross-sections of heat transfer tubes 11 parallel to the principal surface of the fin 12. In Modification 8 shown in Fig. 31 too, as in the case of Embodiment 2, the fin projections 122 include intermediate fin projections 122C. Fig. 32 is a cross-sectional view taken along line C-C in Fig. 31.

[0116] As shown in Fig. 31, in Modification 8 of Embodiment 2, the intermediate fin projections 122C include first intermediate fin projections 122C-1 and second intermediate fin projections 122C-2. The first intermediate fin projections 122C-1 have the shapes of oblongs whose long sides extend in the Z direction when viewed from the Y direction. Further, the second intermediate fin projections 122C-2 have the shapes of circles when viewed from the Y direction. Differences between Modification 8 and Embodiment 2 lie in that in Modification 8, the intermediate fin projections 122C include the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2. Further, the shapes of the intermediate fin projections 122C in Embodiment 2 and the shapes of the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 in Modification 8 are different from each other. Other components and workings are not described here, as they are the same as those of Embodiment 2.

[0117] The first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 are described with reference to Fig. 31. Each of the first intermediate fin projections 122C-1 is configured such that the first raised portion 122c1-1 and the second raised portion 122c1-2 are equal in length to each other. The distance between each of the first intermediate fin projections 122C-1 and the center line CL is longer than the distance between each of the second intermediate fin projections 122C-2 and the center line CL. It should be noted that differences between the intermediate fin projections 122C in Embodiment 2 and the intermediate fin projections 122C in Modification 8 lie in relationships in length between the first raised portions 122c-1 and the second raised portions 122c-2.

[0118] Further, the number of first intermediate fin projections 122C-1 is not limited to 2, although two first intermediate fin projections 122C-1 are provided in Fig. 31. One first intermediate fin projection 122C-1 may be provided, or three or more first intermediate fin projections 122C-1 may be provided. Further, the number of second intermediate fin projections 122C-2 is not limited to 2, although two second intermediate fin projections 122C-2 are provided in Fig. 31. One second intermediate fin projection 122C-2 may be provided, or three or more second intermediate fin projections 122C-2 may be provided.

[0119] As mentioned above, in Modification 8, the first intermediate fin projections 122C-1, which linearly extend along the longitudinal direction of the fin 12, are provided. Further, at positions where the distance between the first outer fin projection 122B-1 and the second outer fin projection 122B2 is relatively short, the circular second intermediate fin projections 122C-2, whose lengths along the longitudinal direction of the fin 12 are relatively short, are provided to reduce the area of a flat portion of the fin 12. In Modification 8, providing the first intermediate fin projections 122C-1 and the second intermediate fin projections 122C-2 brings about improvement in longitudinal strength of the fin 12 and improvement in heat transfer coefficient of the surface of the fin 12.

[0120] As mentioned above, the heat exchanger 100 of any of Embodiment 1, Embodiment 2, and the modifications thereof can be provided in the refrigeration cycle apparatus 1 shown in Fig. 3. In that case, in the refrigeration cycle apparatus 1, the fin projections 122 provided on each of the fins 12 of the heat exchanger 100 brings about an increase in longitudinal direction of the fin 12 and improvement in formability of the fin. This brings about improvement in manufacturability of the heat exchanger 100, resulting in improvement in manufacturability of the refrigeration cycle apparatus 1 as a whole. Further, the fin projections 122 provided on each of the fins 12 of the heat exchanger 100 make it easy for air to make contact with the surface of the fin 12. This brings about improvement in heat transfer coefficient of the heat exchanger 100, resulting in improvement in energy efficiency of the refrigeration cycle apparatus 1 as a whole.

[0121] While the foregoing has described Embodiment 1, Embodiment 2, and the modifications thereof, the heat exchanger 100 and the refrigeration cycle apparatus 1 are not limited to Embodiment 1, Embodiment 2, or the modifications thereof and may be altered or applied in various ways without departing from the scope of the disclosure. Embodiment 1, Embodiment 2, and the modifications thereof may be combined with one another to such an extent as not to impair the functions or structures of the embodiments or the modifications.

Reference Signs List

[0122] 1: refrigeration cycle apparatus, 2: heat source side unit, 3: load side unit, 4: compressor, 5: flow switching device, 6: expansion valve, 7A: air-sending device, 7B: air-sending device, 7a: fan motor, 7b: fan, 8: refrigerant pipe, 9A: controller, 9B: controller, 11: heat transfer tube, 11A: heat transfer tube, 11B: heat transfer tube, 11a: U-tube, 12: fin, 12a: leading edge, 12b: trailing edge, 12c: through hole, 12d: fin collar, 100: heat exchanger, 100A: heat exchanger, 100B: heat exchanger, 121: fin base surface, 121A: first flat portion, 121B: second flat portion, 122: fin projection, 122A: inner fin projection, 122A-1 : first inner fin projection, 122A-2: second inner fin projection, 122B: outer fin projection, 122B-1 : first outer fin projection, 122B-2: second outer fin projection, 122B-3: third outer fin projection, 122C: intermediate fin projection, 122C-1 : first intermediate fin projection, 122C-2: second intermediate fin projection, 122c-1 : first raised portion, 122c-1a: first end, 122c-1b: second end, 122c-2: second raised portion, 122c-2a: first end, 122c-2b: second end, 122c1-1 : first raised portion, 122c1-1a: first end, 122c1-1b: second end, 122c1-2: second raised portion, 122c1-2a: first end, 122c1-2b: second end, 122c2-1 : first raised portion, 122c2-1a: first end, 122c2-1b: second end, 122c2-2: second raised portion, 122c2-2a: first end, 122c2-2b: second end, 122D: additional fin projection, Y: first direction, Z: second direction, X: third direction, CL: center line, VL1 : first virtual line, VL2: second virtual line

Claims

1. A heat exchanger comprising:

   a plurality of fins being spaced apart from one another in a first direction; and
   a plurality of heat transfer tubes penetrating through the plurality of fins, the plurality of heat transfer tubes being spaced apart from one another in a second direction crossing the first direction,
   wherein
   each of the plurality of fins includes

      a fin base surface that is flat, and
      a plurality of fin projections, and

   the plurality of fin projections include

      inner fin projections provided to separately surround each of the plurality of heat transfer tubes, the inner fin projections protruding in the first direction from the fin base surface, and
      outer fin projections provided to separately surround each of the inner fin projections, the outer fin projections protruding in the first direction from the fin base surface.

2. The heat exchanger of claim 1, wherein

   the plurality of heat transfer tubes are circular in cross-section, and
   each of the inner fin projections and a corresponding one of the outer fin projections are provided concentrically with a corresponding one of the plurality of heat transfer tubes.

3. The heat exchanger of claim 1 or 2, wherein the fin base surface has first flat portions between the inner

fin projections and the outer fin projections.

4. The heat exchanger of any one of claims 1 to 3, wherein assuming h1 is a height of each of the inner fin projections from the fin base surface and that h2 is a height of each of the outer fin projections from the fin base surface, a relationship between the height h1 and the height h2 is expressed as $h2 \leq h1$.

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

the plurality of heat transfer tubes include a first heat transfer tube and a second heat transfer tube that are adjacent to each other in the second direction,
the inner fin projections include

a first inner fin projection provided to surround the first heat transfer tube,
and
a second inner fin projection provided to surround the second heat transfer tube,

the outer fin projections include

a first outer fin projection provided to surround the first inner fin projection,
and
a second outer fin projection provided to surround the second inner fin projection,
and

the fin base surface has a second flat portion between the first outer fin projection and the second outer fin projection.

6. The heat exchanger of claim 5, wherein

the plurality of fin projections include an intermediate fin projection protruding in the first direction from the fin base surface, and
the intermediate fin projection is provided so that at least part of the intermediate fin projection is located between the first outer fin projection and the second outer fin projection.

7. The heat exchanger of claim 6, wherein in the first direction, a direction in which the inner fin projections protrude from the fin base surface and a direction in which the intermediate fin projection protrudes from the fin base surface are opposite to each other.

8. The heat exchanger of claim 6 or 7, wherein the intermediate fin projection is provided at a position not crossing a center line passing through a center of the first heat transfer tube and a center of the second heat transfer tube along the second direction.

9. The heat exchanger of claim 8, wherein

assuming that a transverse direction of the plurality of fins is a third direction crossing the first direction and the second direction,
the intermediate fin projection includes

a first raised portion extending in the second direction, the first raised portion being raised from the fin base surface, and
a second raised portion extending parallel to the first raised portion, the second raised portion raised from the fin base surface,

in the second direction, the first raised portion is greater in length than the second raised portion,
in the third direction, a distance between the first raised portion and the center line is longer than a distance between the second raised portion and the center line,
in the second direction, the first raised portion includes

a first end provided adjacent to the first outer fin projection, and
a second end provided adjacent to the second outer fin projection,

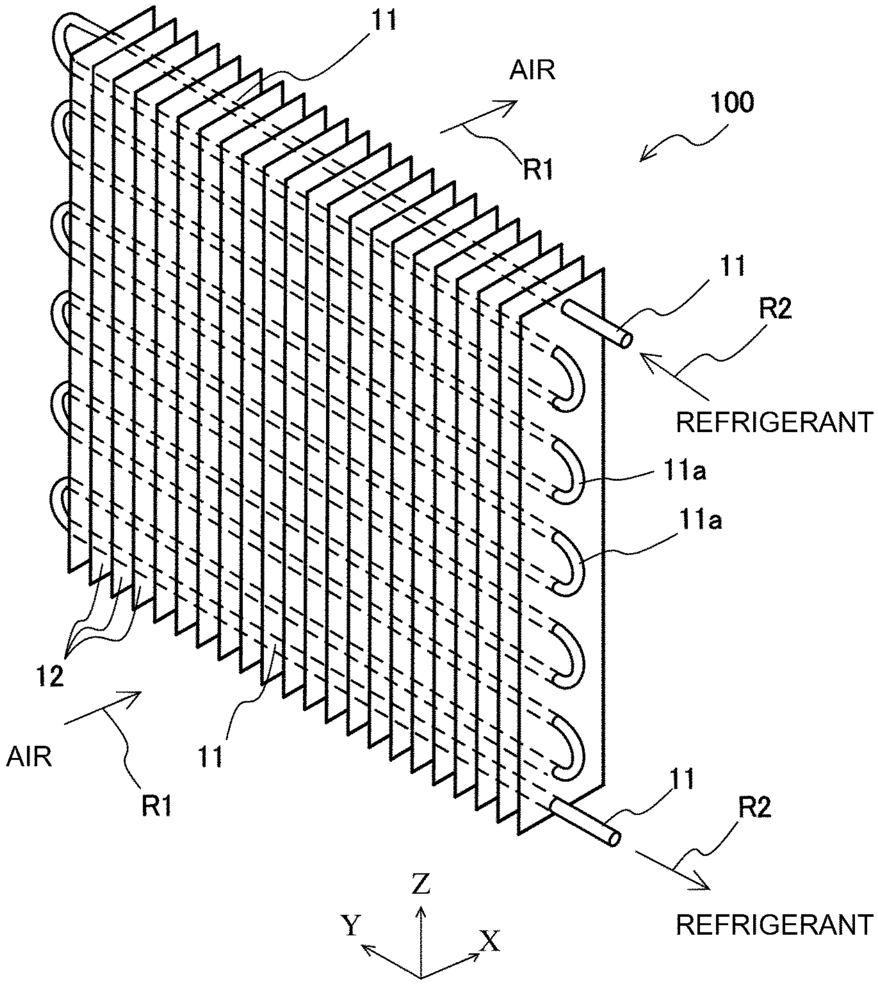
in the second direction, the second raised portion includes

a first end provided adjacent to the first outer fin projection, and
a second end provided adjacent to the second outer fin projection,

a first virtual line passing through the first end of the first raised portion and the first end of the second raised portion does not cross the first outer fin projection, and
a second virtual line passing through the second end of the first raised portion and the second end of the second raised portion does not cross the second outer fin projection.

10. A refrigeration cycle apparatus comprising the heat exchanger of any one of claims 1 to 9 as a condenser or an evaporator.

FIG. 1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AIR
100
R1
11
R2
REFRIGERANT
11a
11a
12
AIR
11
R1
11
R2
REFRIGERANT
Z
Y
X

FIG. 2

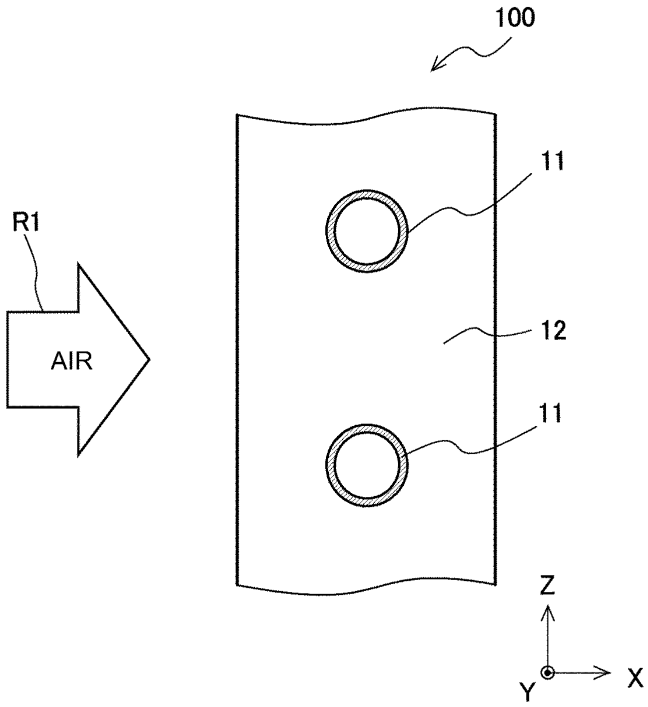

100
11
R1
12
AIR
11
Z
Y
X

FIG. 3

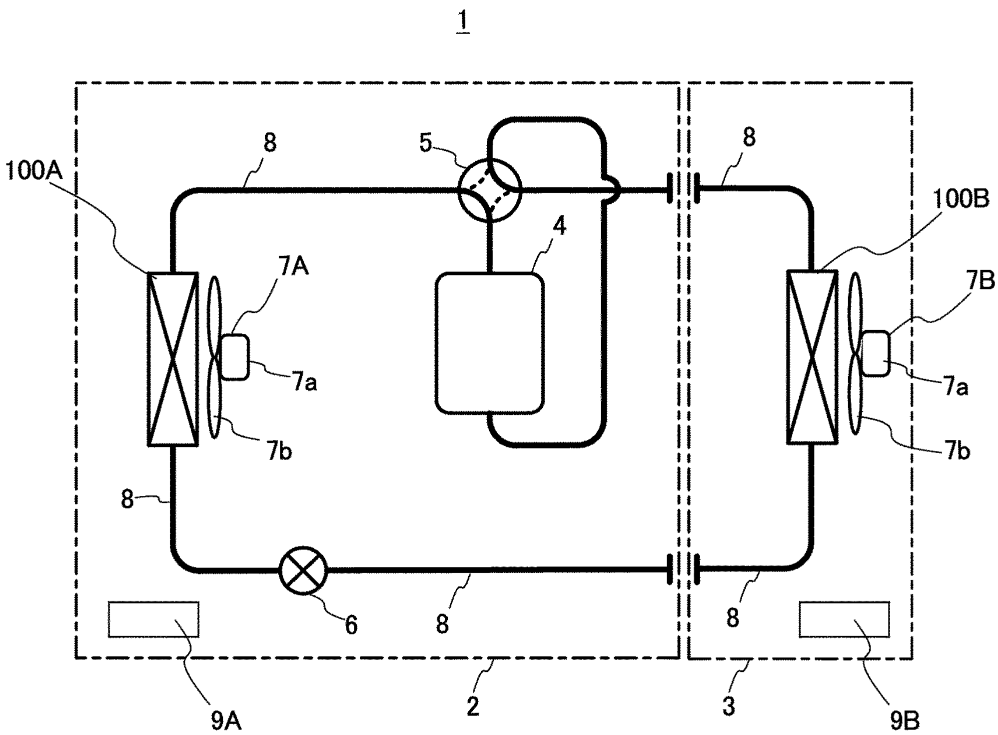

1
100A
8
5
8
100B
4
7A
7B
7a
7a
7b
7b
8
6
8
8
9A
2
3
9B

FIG. 4

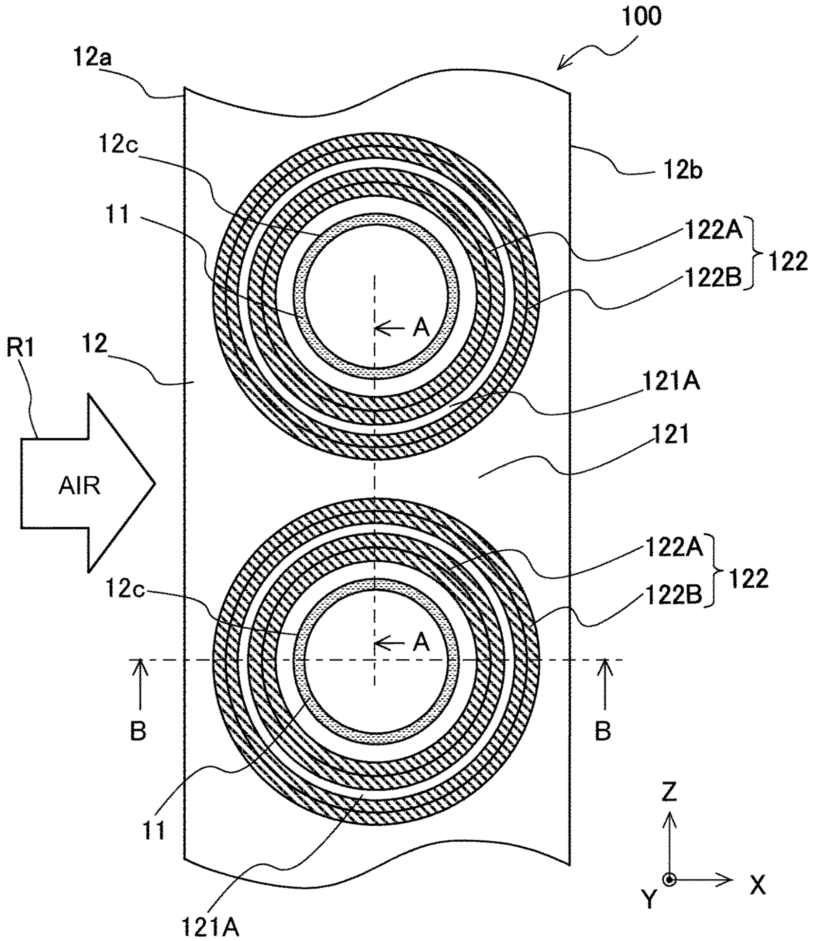

100
12a
12b
12c
11
122A
122
122B
R1
12
121A
121
AIR
122A
122
122B
12c
A
B
B
11
121A
Z
X
Y

FIG. 5

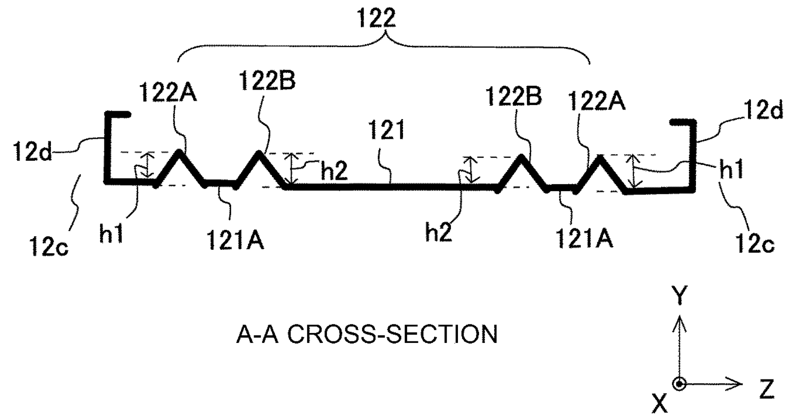
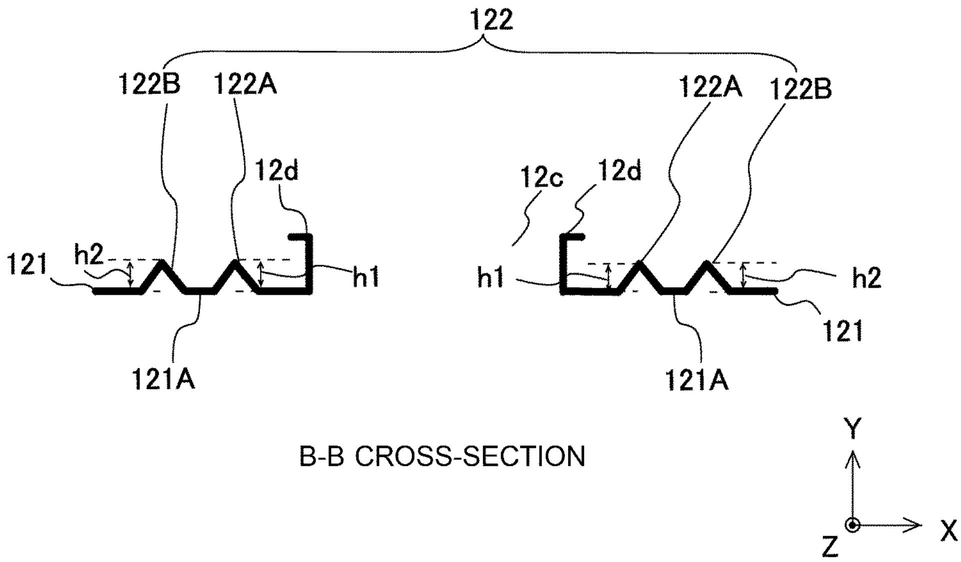

122
122A
122B
122B
122A
12d
12d
121
h2
h1
12c
h1
121A
h2
121A
12c
A-A CROSS-SECTION
Y
Z
X

FIG. 6



B-B CROSS-SECTION

FIG. 7

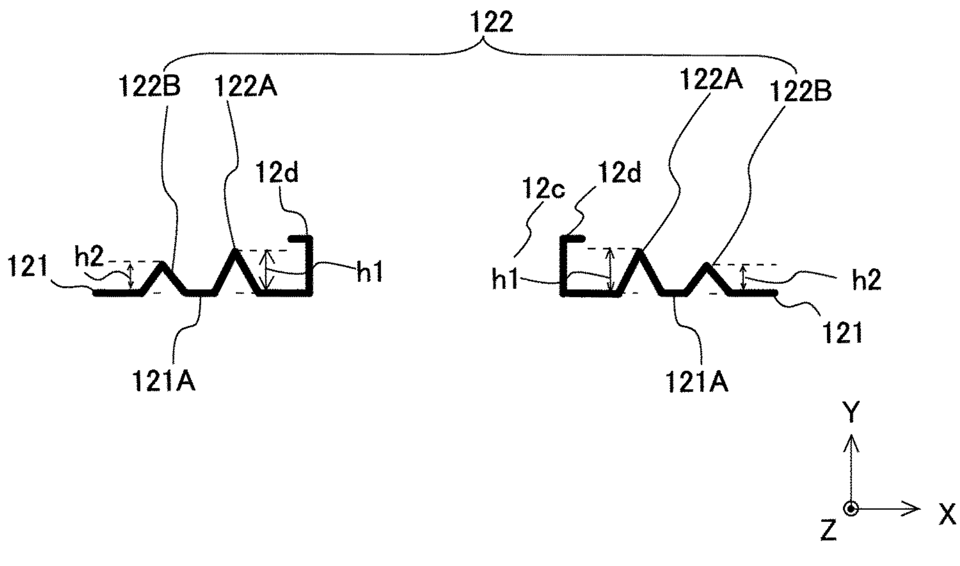


FIG. 8

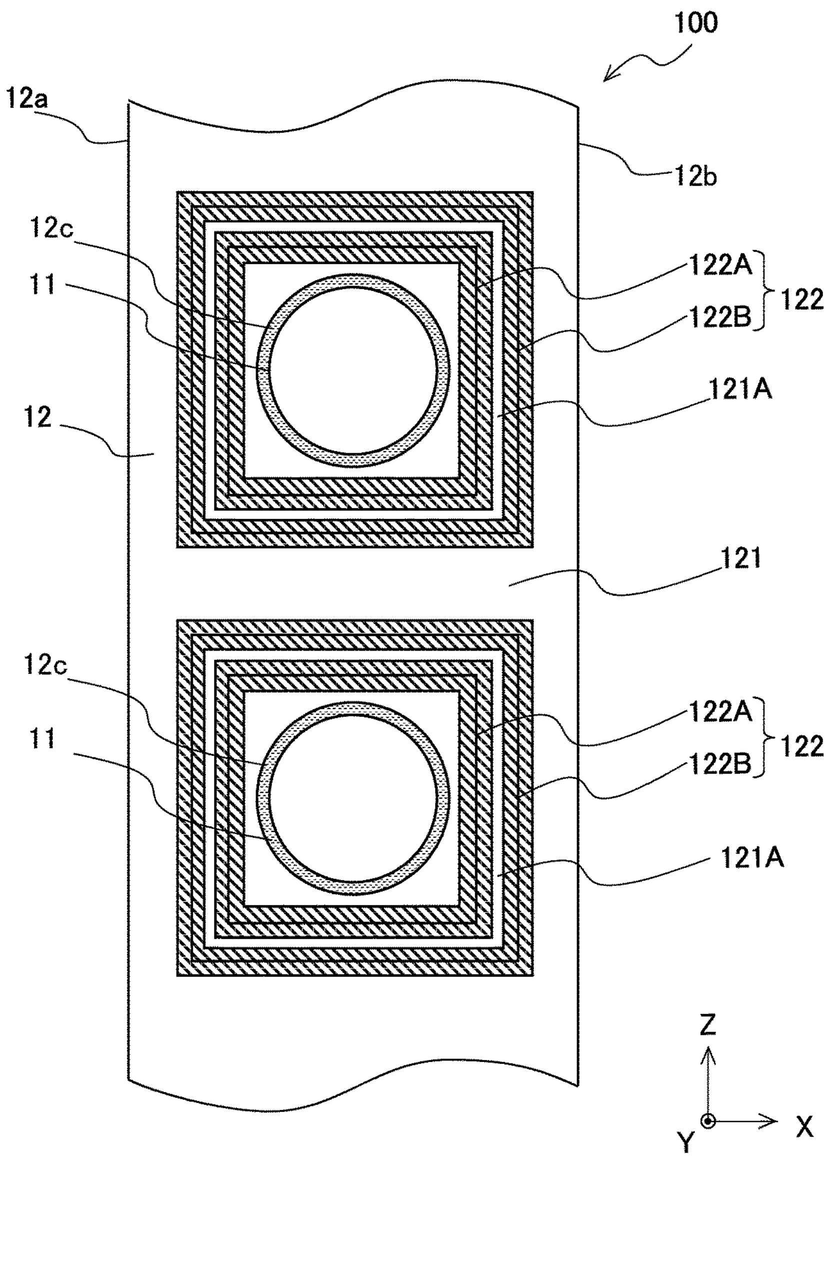

100
12a
12b
12c
11
122A
122B
122
121A
12
121
12c
11
122A
122B
122
121A
Z
Y
X

FIG. 9

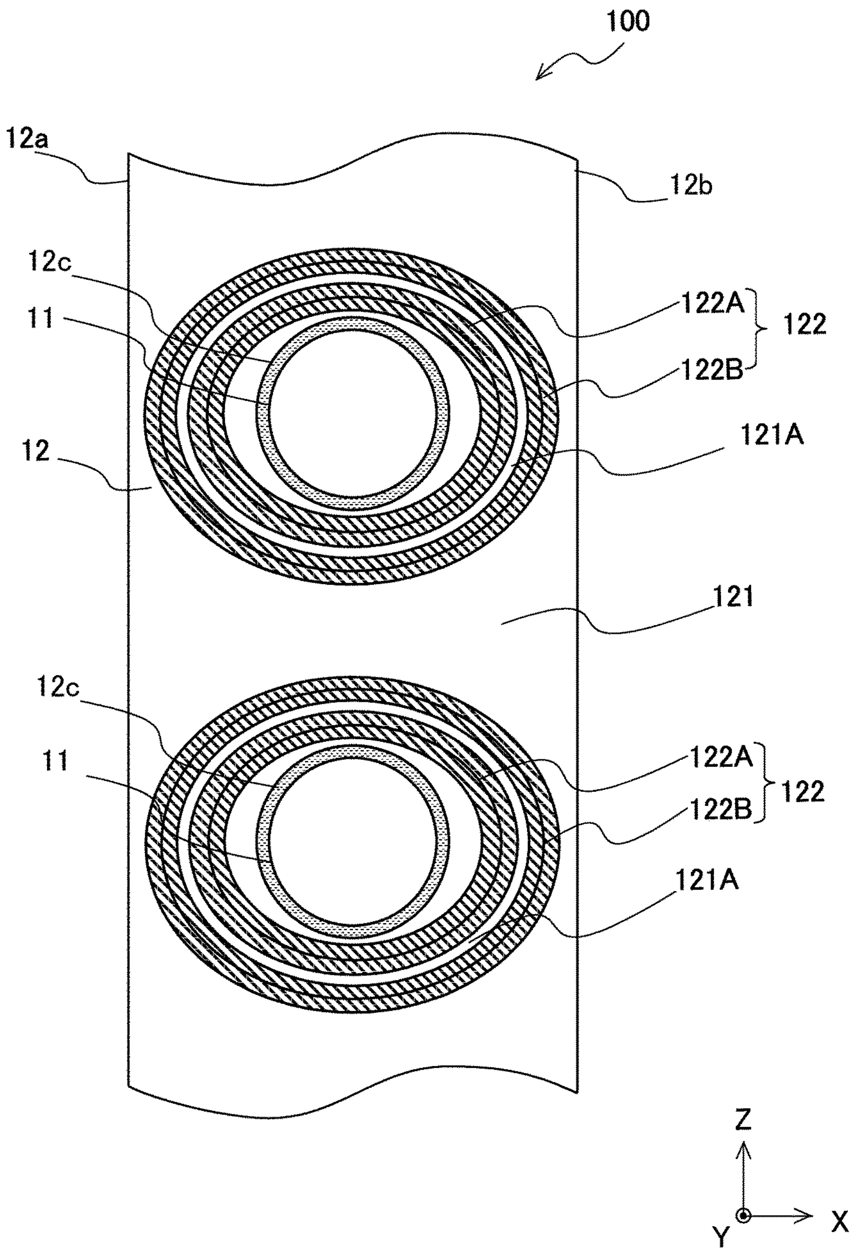

100
12a
12b
12c
11
122A
122
122B
121A
12
121
12c
11
122A
122
122B
121A
Z
X
Y

FIG. 10

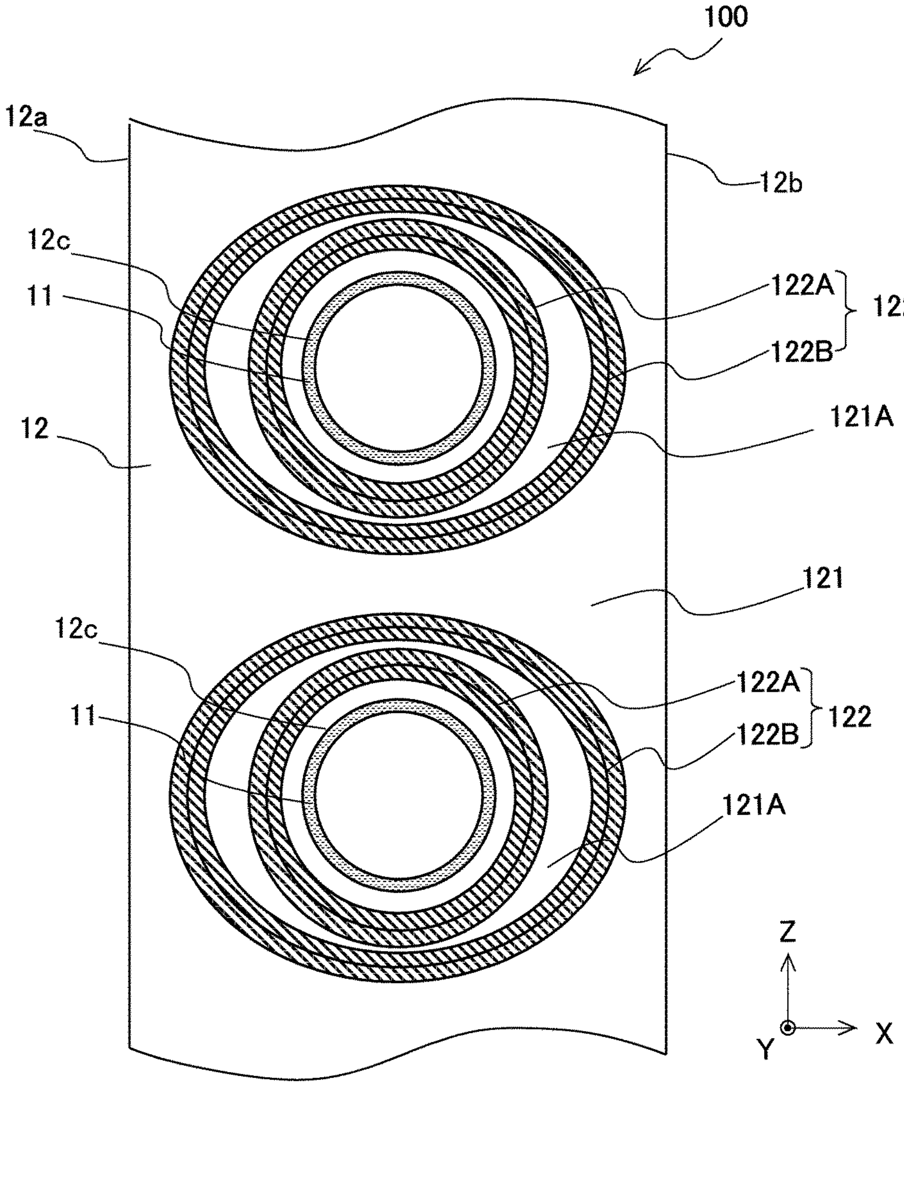

100
12a
12b
12c
11
122A
122
122B
121A
12
121
12c
11
122A
122
122B
121A
Z
Y
X

FIG. 11

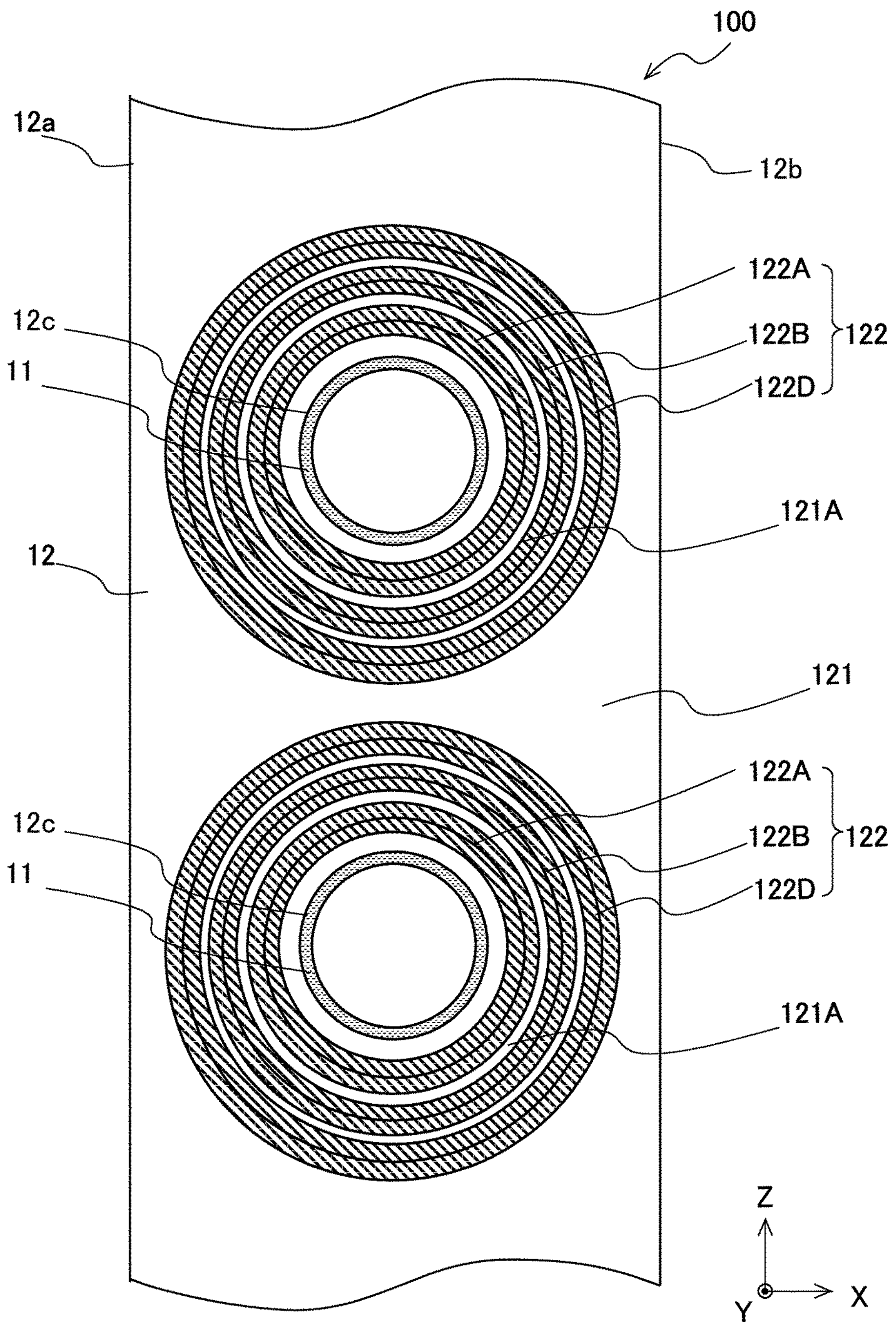

100
12a
12b
122A
12c
122B
122
11
122D
121A
12
121
122A
12c
122B
122
11
122D
121A
Z
Y
X

FIG. 12

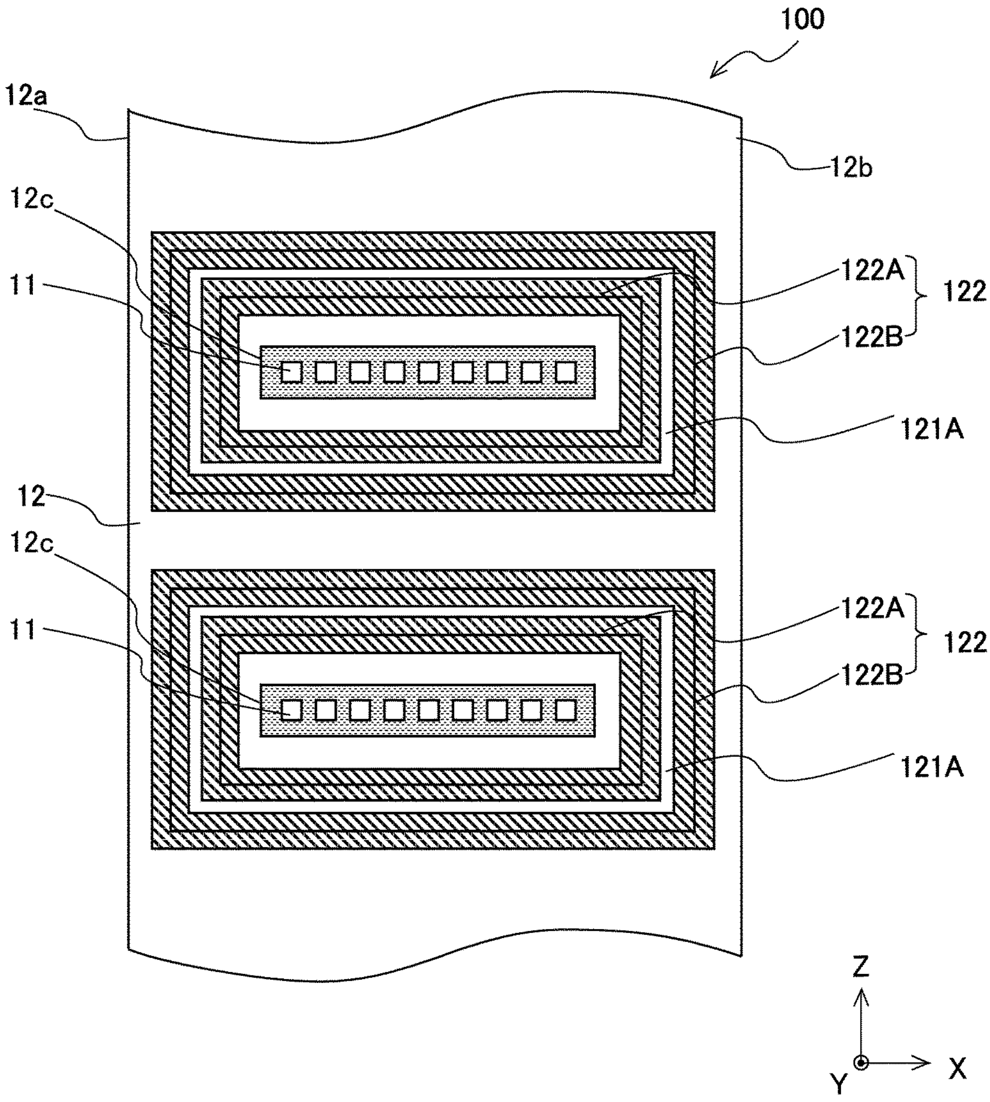

100
12a
12b
12c
11
122A
122
122B
121A
12
12c
11
122A
122
122B
121A
Z
Y
X

FIG. 13

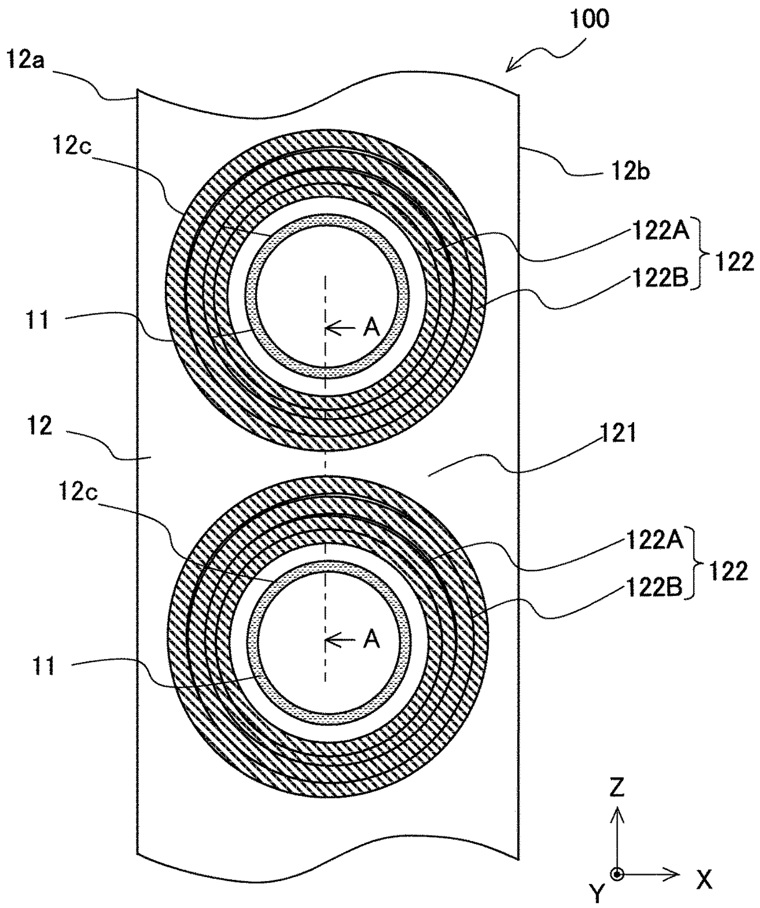
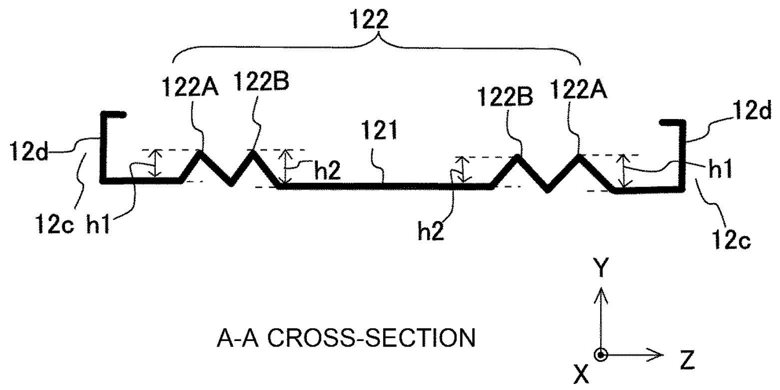


FIG. 14



A-A CROSS-SECTION

FIG. 15

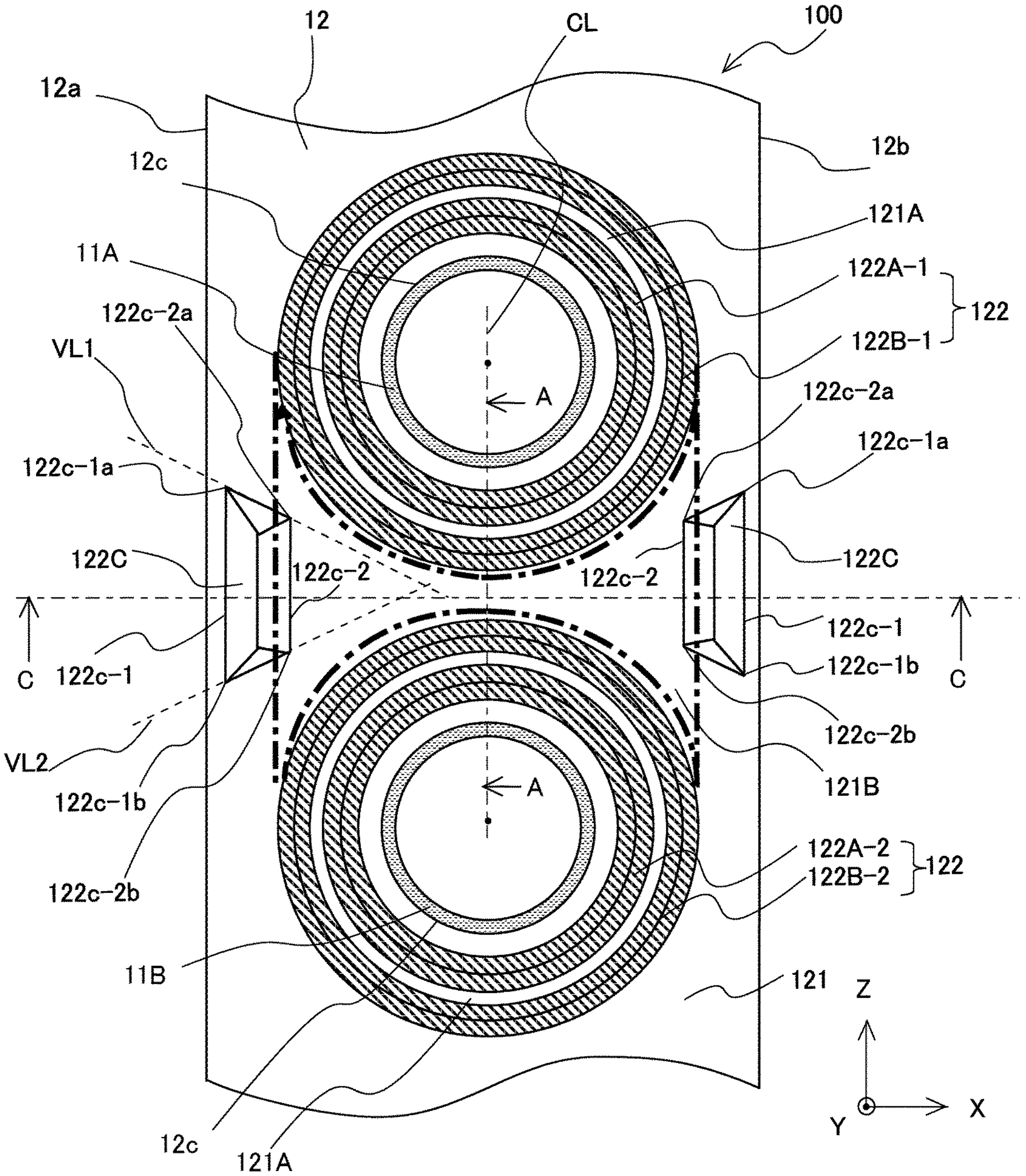
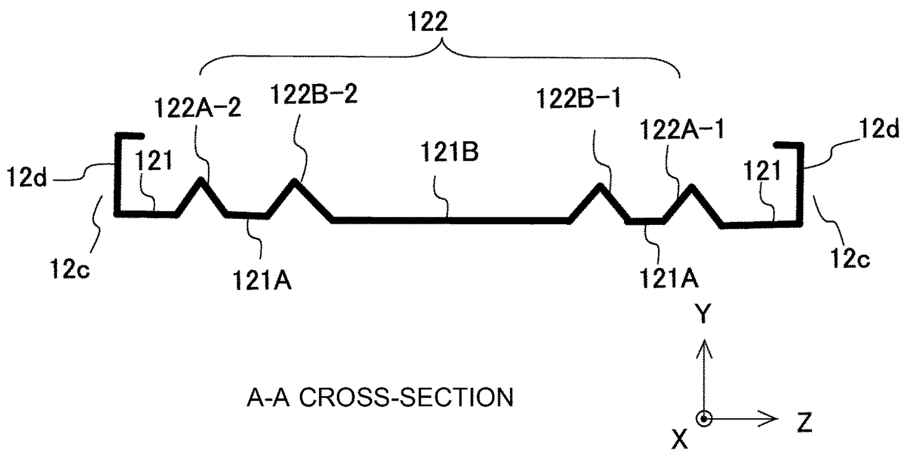
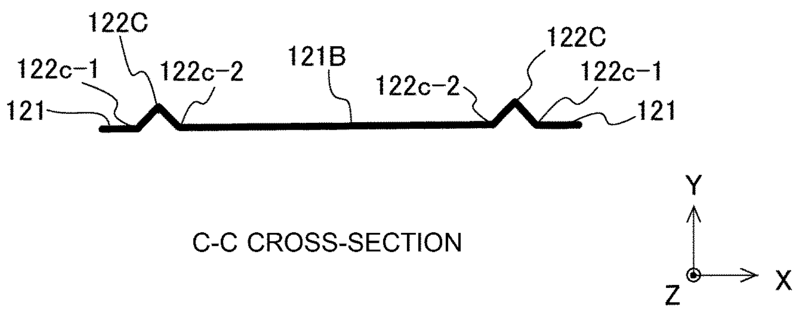

12
CL
100
12a
12b
12c
121A
11A
122A-1
122
122B-1
122c-2a
VL1
A
122c-1a
122C
122c-2
C
122c-1
122c-1b
VL2
122c-2b
121B
122A-2
122B-2
11B
121
Z
Y
X

FIG. 16



A-A CROSS-SECTION

FIG. 17



C-C CROSS-SECTION

FIG. 18

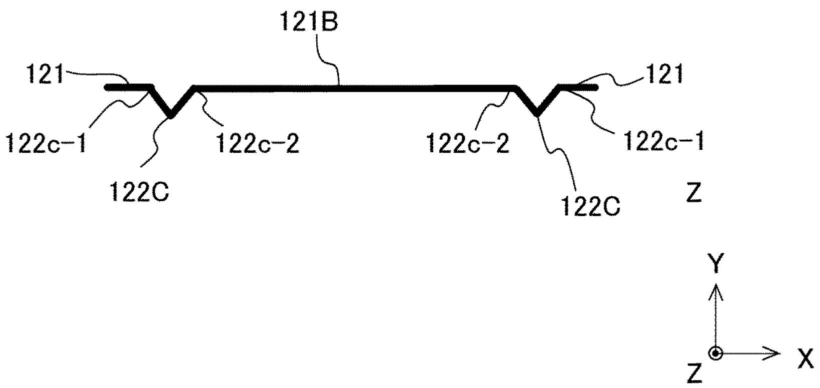


FIG. 19

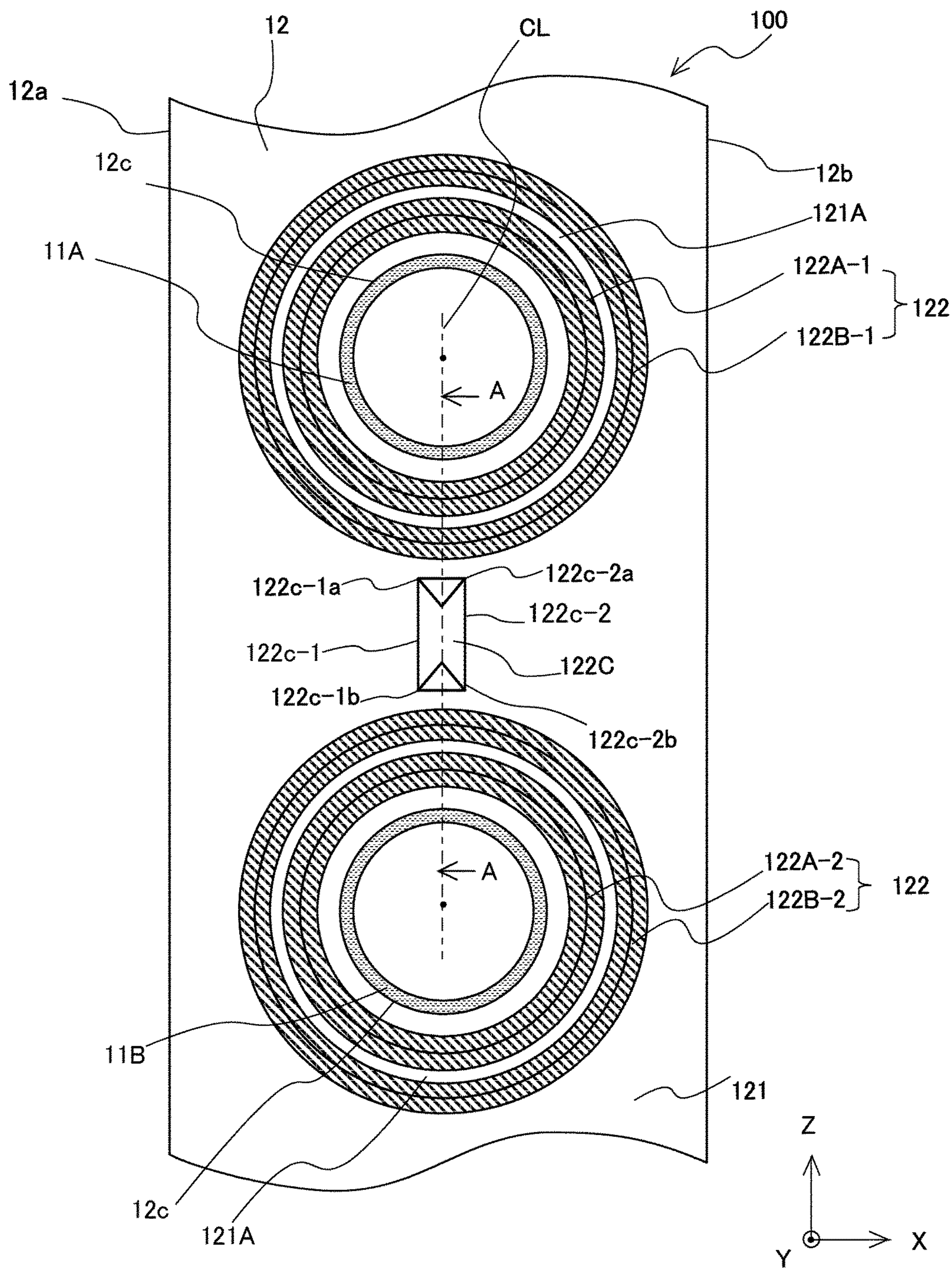
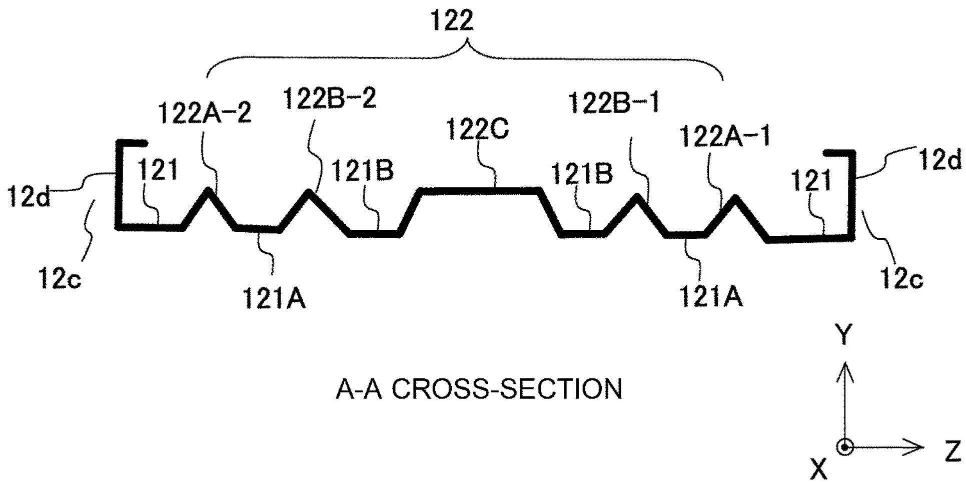

12
CL
100
12a
12c
12b
121A
11A
122A-1
122
122B-1
A
122c-1a
122c-2a
122c-2
122c-1
122C
122c-1b
122c-2b
A
122A-2
122B-2
122
11B
121
Z
12c
121A
Y
X

FIG. 20



A-A CROSS-SECTION

FIG. 21

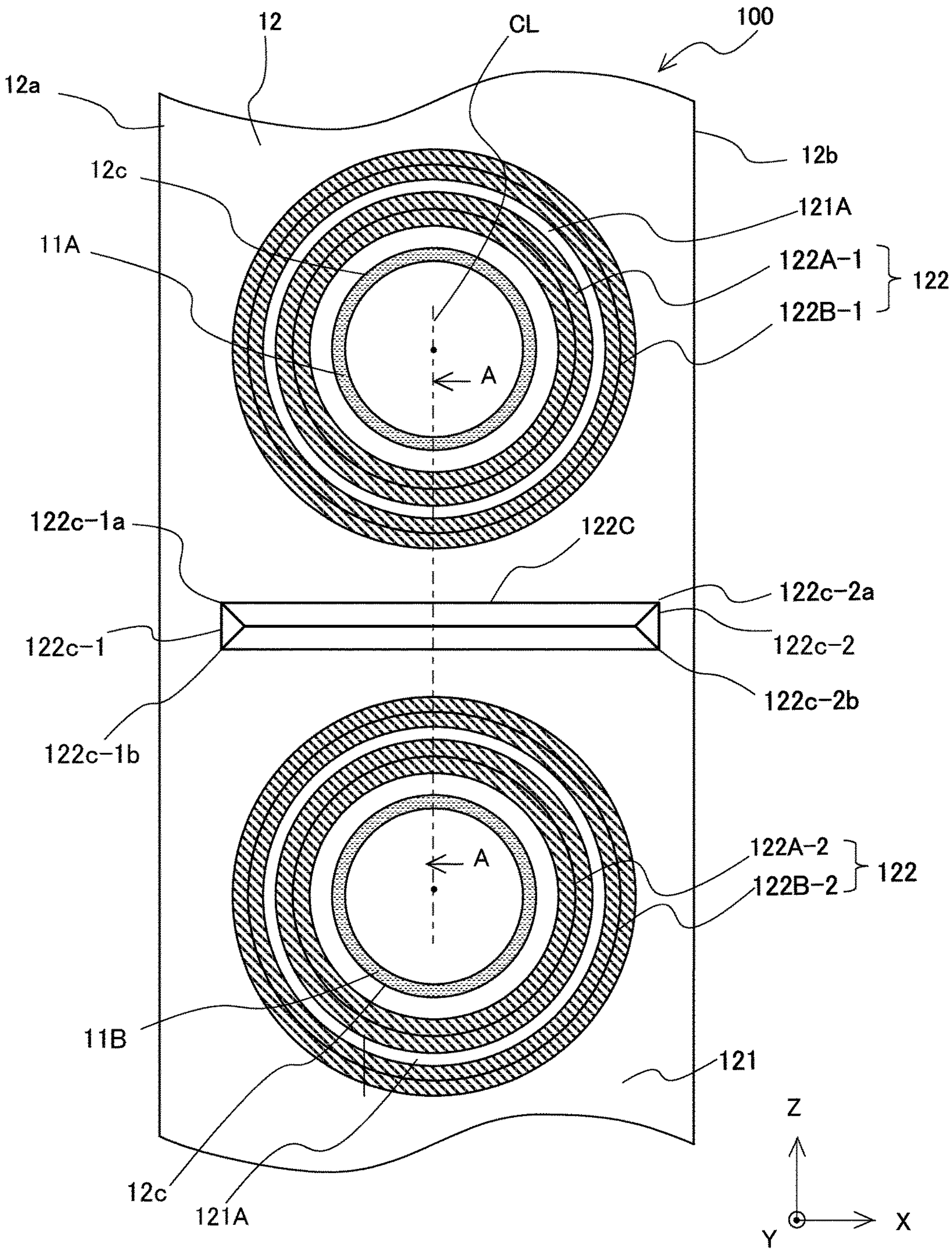
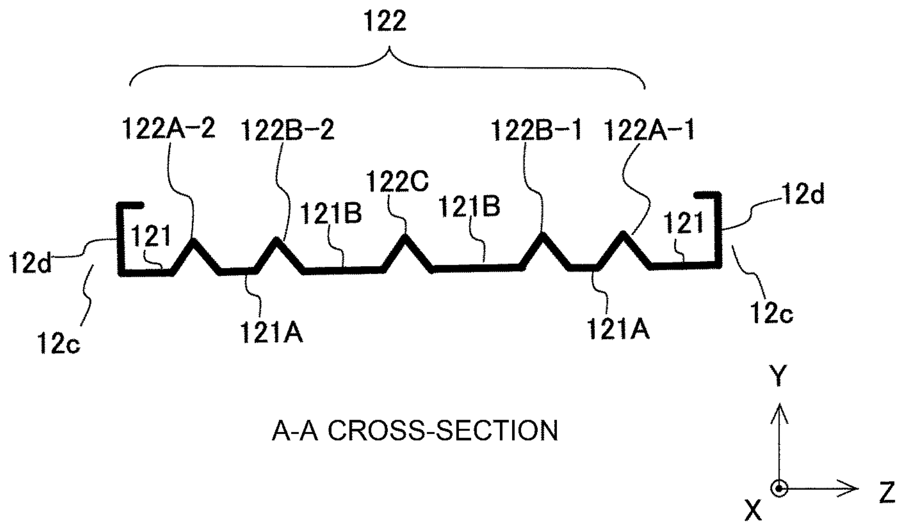
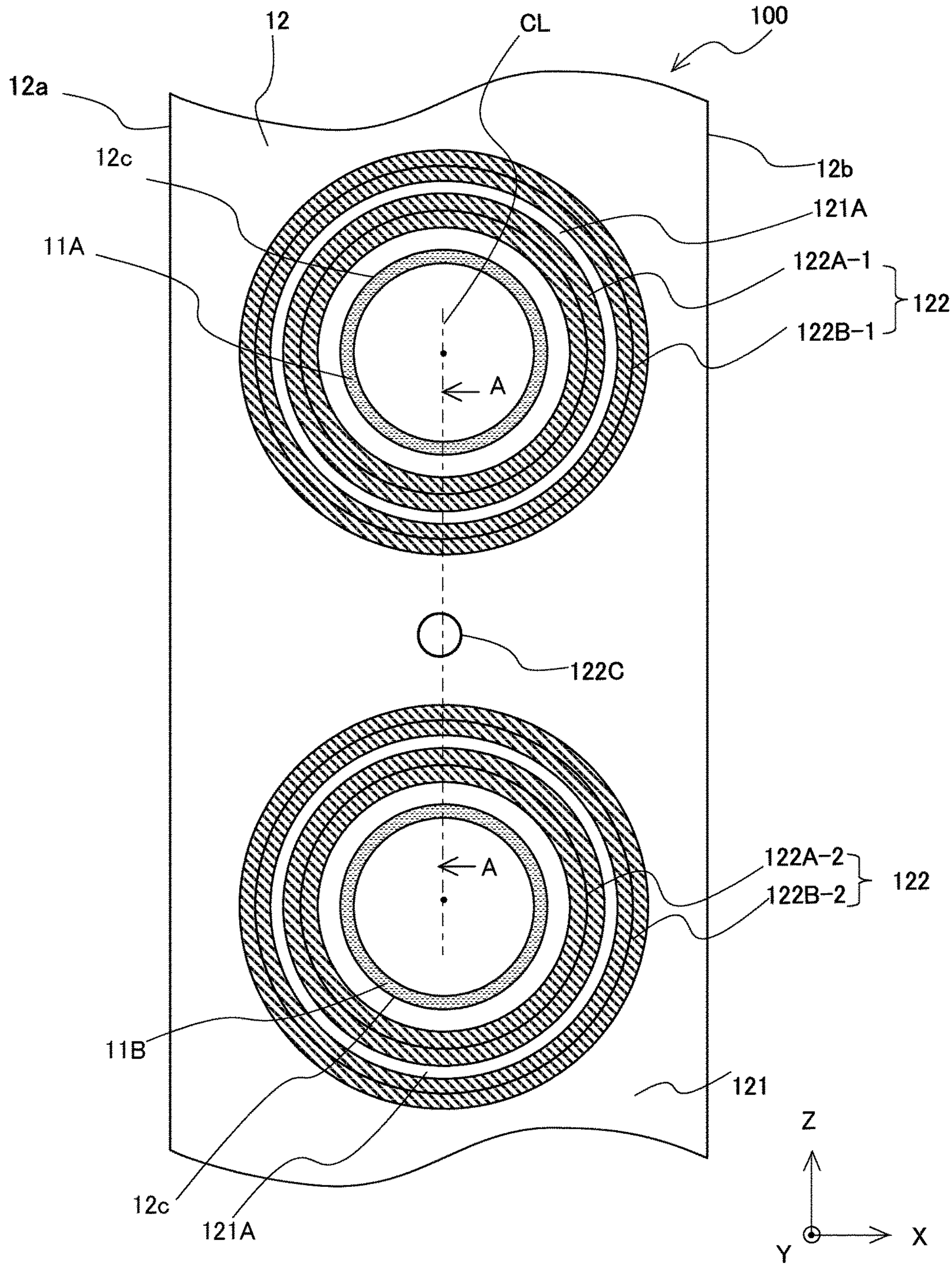

12
CL
100
12a
12b
12c
121A
11A
122A-1
122
122B-1
A
122c-1a
122C
122c-2a
122c-1
122c-2
122c-2b
122c-1b
A
122A-2
122
122B-2
11B
121
Z
12c
121A
Y
X

FIG. 22



A-A CROSS-SECTION

FIG. 23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CL
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12b
12c
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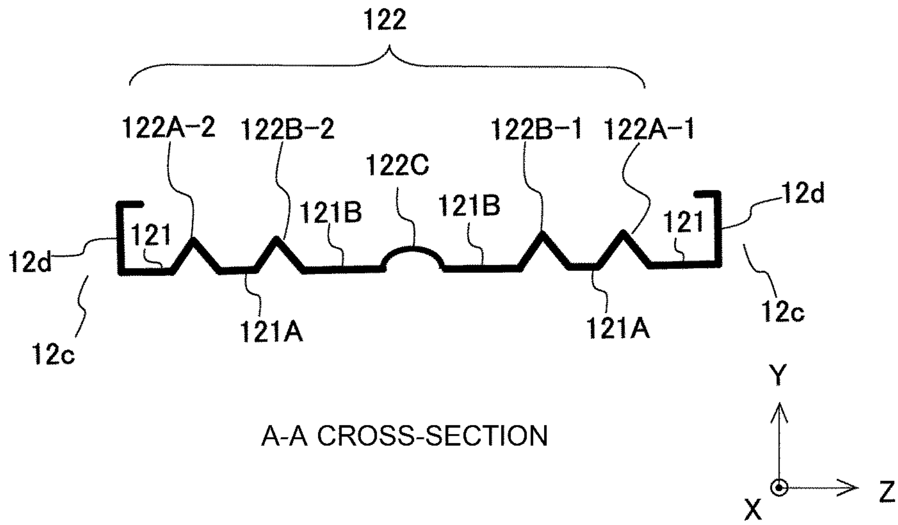
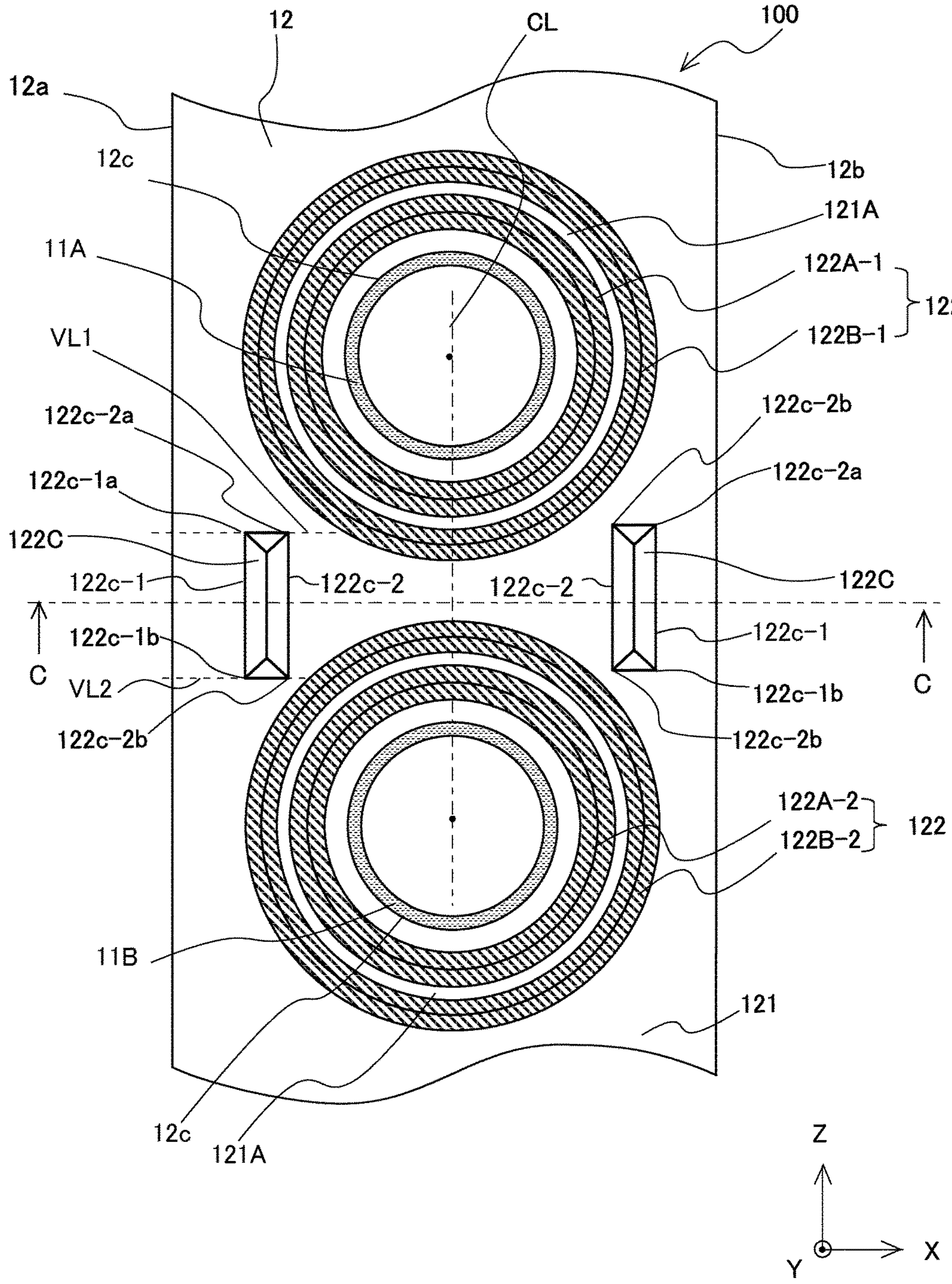
11A
122A-1
122
122B-1
A
122C
122A-2
122
122B-2
A
11B
121
Z
12c
121A
Y
X

FIG. 24



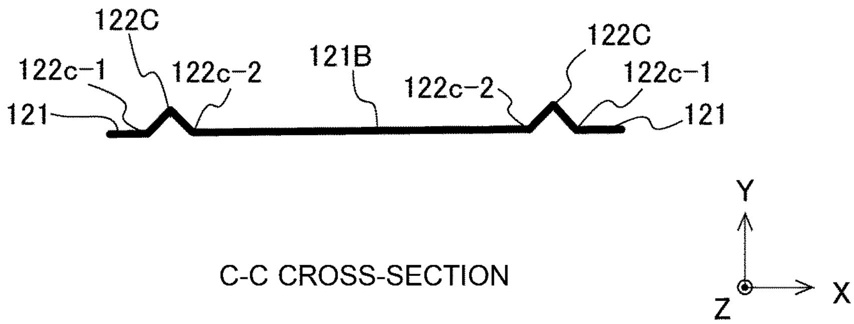
A-A CROSS-SECTION

FIG. 25



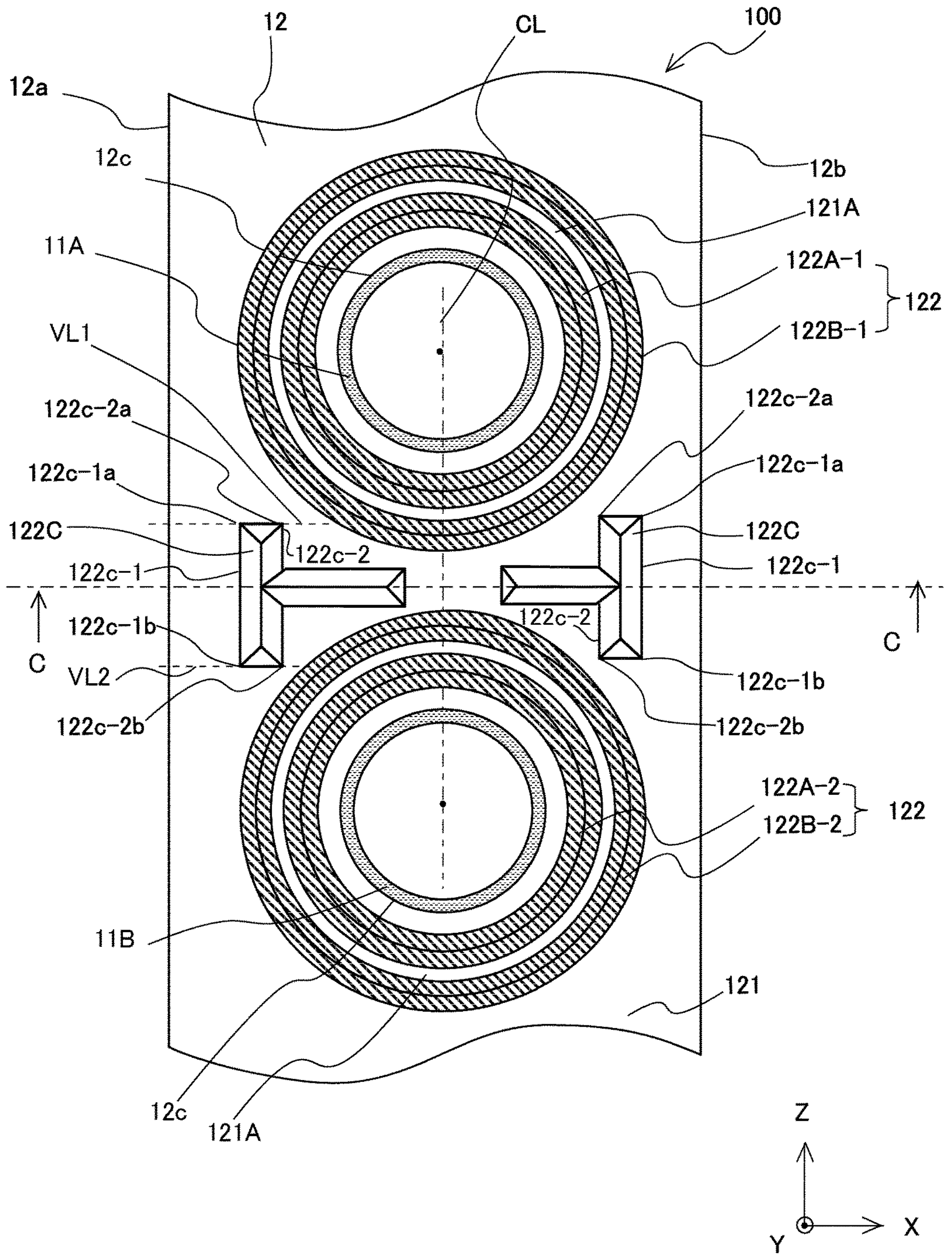
12
CL
100
12a
12b
12c
121A
11A
122A-1
122
122B-1
VL1
122c-2b
122c-2a
122c-1a
122c-2a
122C
122C
122c-1
122c-2
122c-2
C
122c-1
122c-1b
C
VL2
122c-1b
122c-2b
122c-2b
122A-2
122B-2
122
11B
121
12c
121A
Z
X
Y

FIG. 26



C-C CROSS-SECTION

FIG. 27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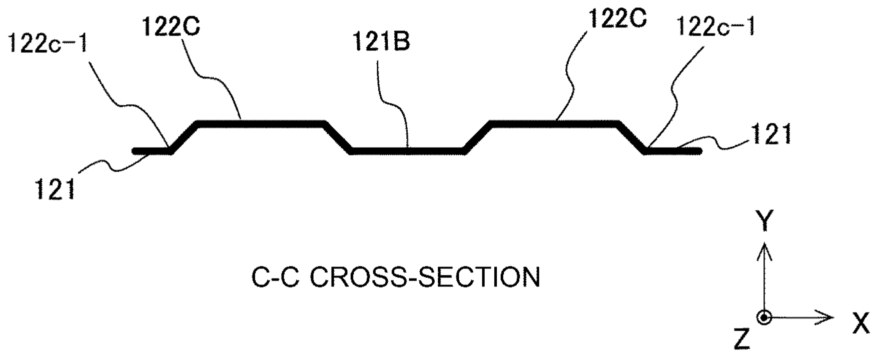
CL
100
12a
12b
12c
121A
11A
122A-1
122
122B-1
VL1
122c-2a
122c-2a
122c-1a
122c-1a
122C
122C
122c-2
122c-1
122c-1
122c-2
C
C
122c-1b
VL2
122c-1b
122c-2b
122c-2b
122A-2
122B-2
122
11B
121
12c
121A
Z
Y
X

FIG. 28



C-C CROSS-SECTION

FIG. 29

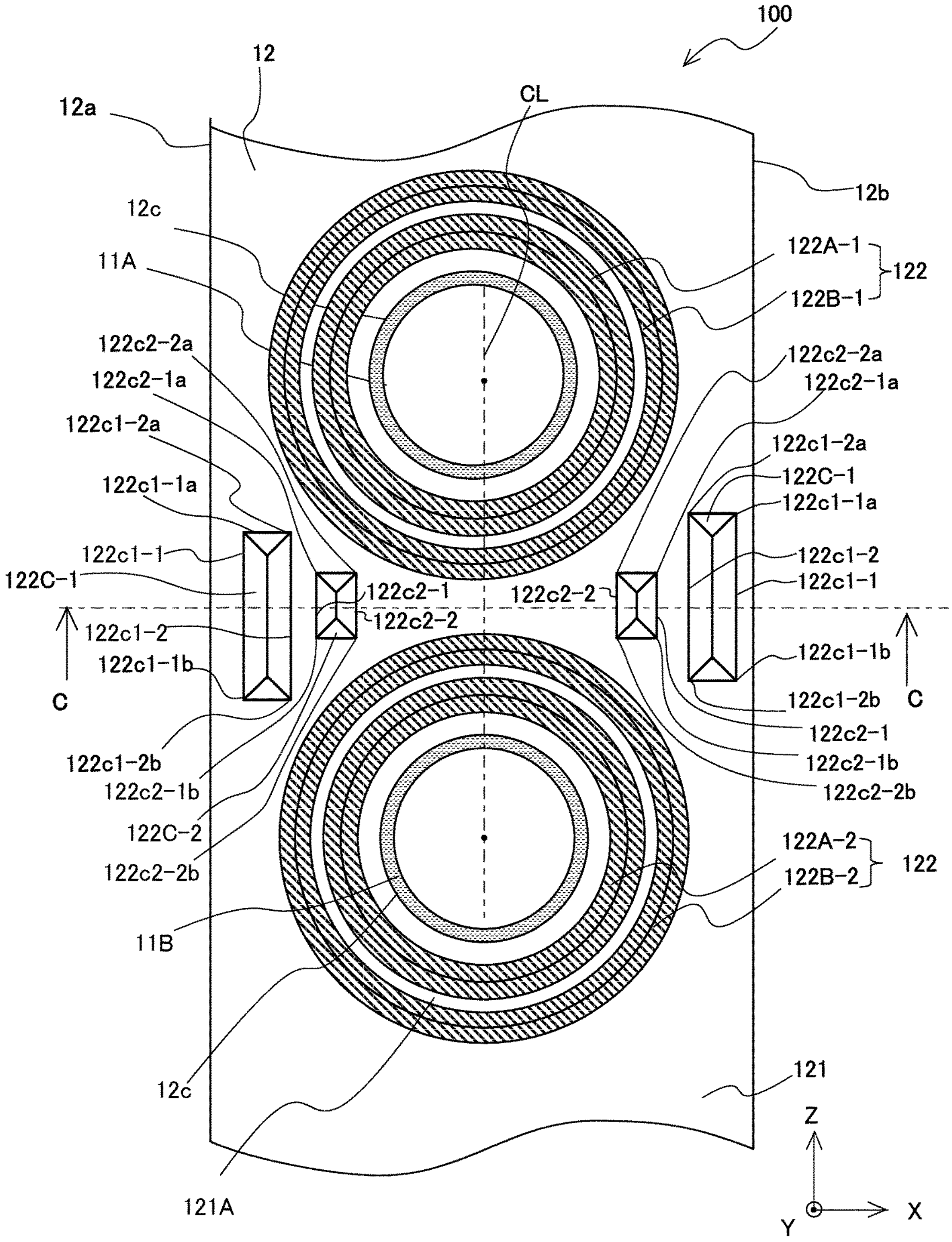
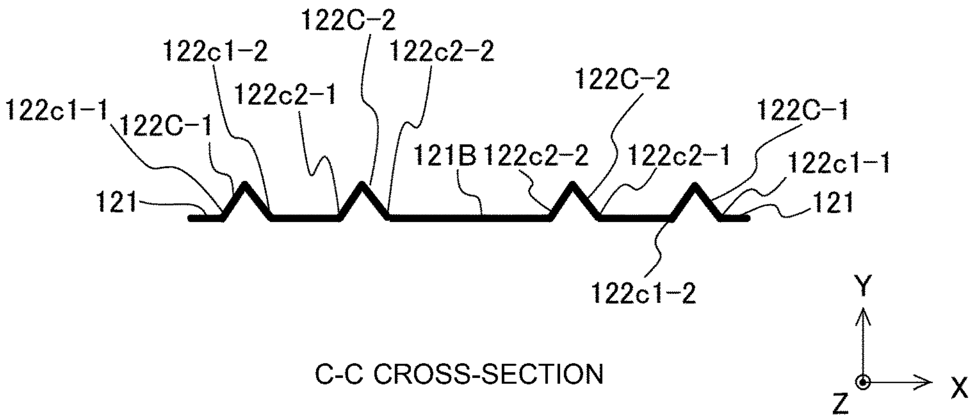

100
12
12a
CL
12b
12c
11A
122A-1
122B-1
122
122c2-2a
122c2-1a
122c1-2a
122c1-1a
122C-1
122c1-1
122c1-2
122c2-1
122c2-2
122c1-1b
C
122c1-2b
122c2-1b
122C-2
122c2-2b
122A-2
122B-2
11B
12c
121
121A
Z
Y
X

FIG. 30



C-C CROSS-SECTION

FIG. 31

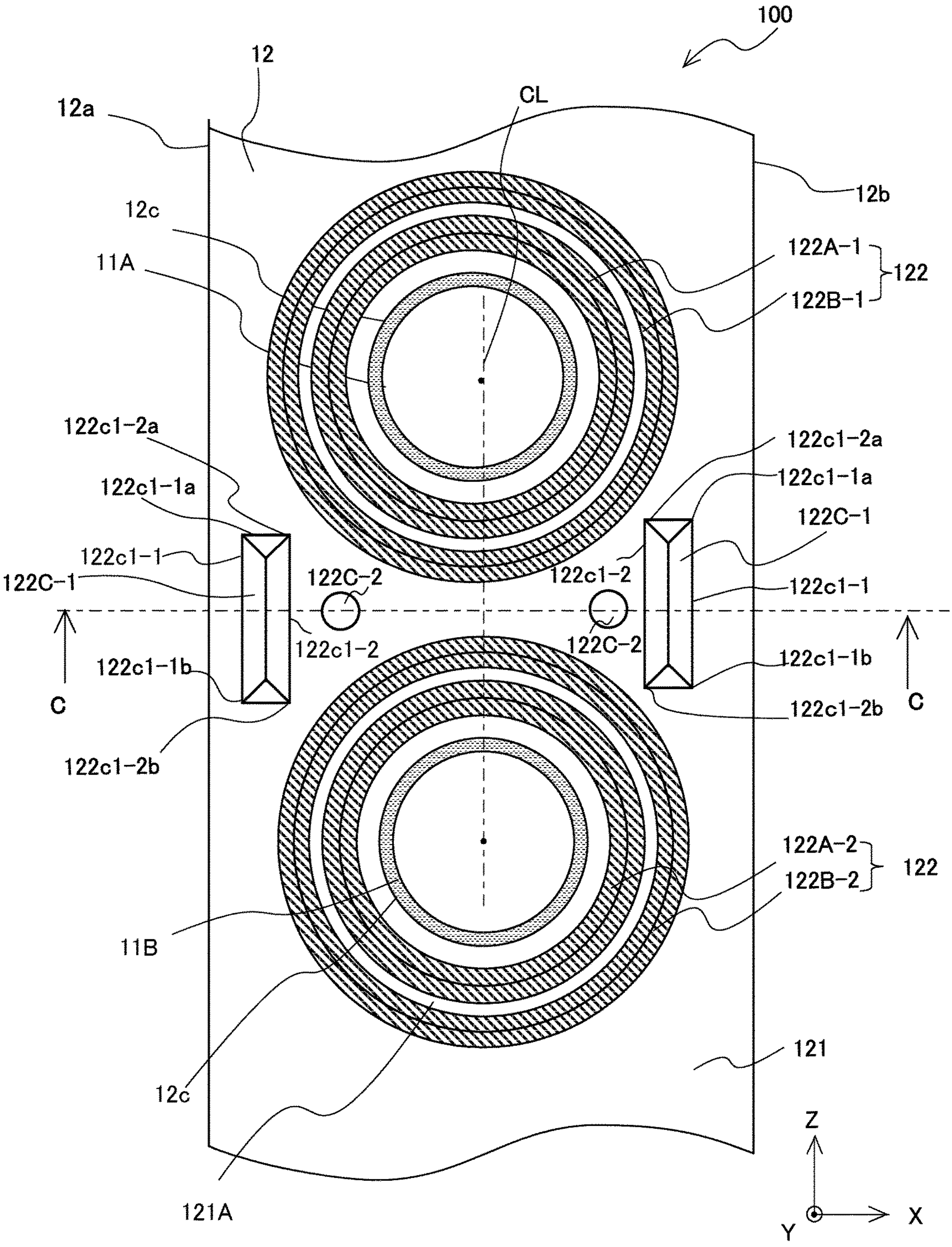
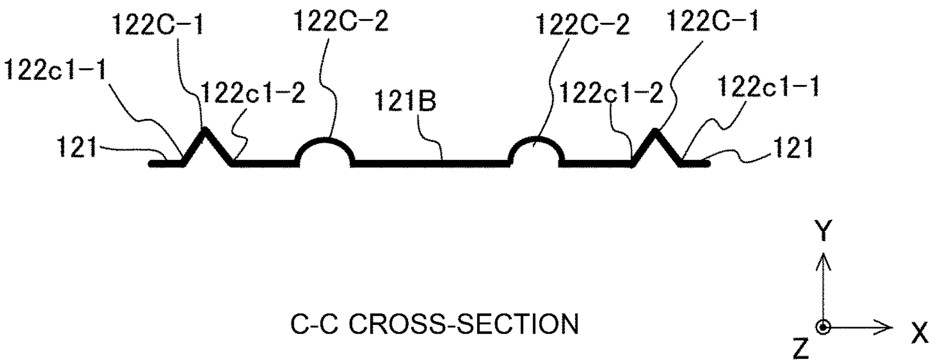

100
12
12a
CL
12b
12c
11A
122A-1
122
122B-1
122c1-2a
122c1-1a
122C-1
122c1-1
122C-2
122c1-2
122c1-1b
C
122c1-2b
122A-2
122B-2
11B
121
12c
121A
Z
Y
X

FIG. 32



C-C CROSS-SECTION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/036077

A. CLASSIFICATION OF SUBJECT MATTER

F25B 39/00(2006.01)i; ***F28D 1/047***(2006.01)i; ***F28F 1/32***(2006.01)i
FI: F28F1/32 L; F28D1/047 B; F25B39/00 D

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28D1/00-13/00; F28F1/24-1/32; F25B39/00-39/04

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.
X A	JP 61-235693 A (MATSUSHITA ELECTRIC IND CO LTD) 20 October 1986 (1986-10-20) specification, p. 2, upper right column, line 14 to lower left column, line 19, fig. 1-2	1-2, 5, 10 3-4, 6-9
Y A	CN 104596343 A (HISENSE-KELON ELECTRICAL HOLDINGS CO., LTD.) 06 May 2015 (2015-05-06) specification, paragraphs [0020]-[0036], fig. 1-6	1–6, 8–10 7
Y	CN 106931538 A (HISENSE (SHANDONG) AIR-CONDITIONING CO LTD) 07 July 2017 (2017-07-07) specification, paragraphs [0023]-[0028], fig. 4-5	1-10
Y	US 2010/0155041 A1 (GEA BATIGNOLLES TECHNOLOGIES THERMIQUES) 24 June 2010 (2010-06-24) specification, paragraphs [0008]-[0009], [0027]-[0028], fig. 2-3	1-10
Y	US 2014/0262156 A1 (BRONICKI, Lucien Y.) 18 September 2014 (2014-09-18) specification, paragraphs [0028]-[0032], fig. 1-3	1-10

☑ 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	Date of mailing of the international search report
02 December 2021	**14 December 2021**

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/036077

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2975350 A1 (GEA MASCHINENKUHLTECHNIK GMBH) 20 January 2016 (2016-01-20) paragraphs [0027]-[0041], fig. 1-10	1-10
A	CN 101963472 A (ZHANGJIAGANG HENGQIANG COOLING EQUIPMENT CO., LTD.) 02 February 2011 (2011-02-02) paragraph [0017], fig. 1-3	1-10
A	CN 110726325 A (GUANDONG MIDEA HVAC EQUIPMENT) 24 January 2020 (2020-01-24) paragraphs [0044]-[0104], fig. 1-6	1-10

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/036077

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 61-235693 A	20 October 1986	(Family: none)	
CN 104596343 A	06 May 2015	(Family: none)	
CN 106931538 A	07 July 2017	(Family: none)	
US 2010/0155041 A1	24 June 2010	WO 2010/070216 A1	
		EP 2379977 A1	
		FR 2940422 A1	
		CN 101861506 A	
		KR 10-2010-0103777 A	
		CA 2747353 A1	
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		ES 2399504 T3	
		RU 2011129831 A	
		BR PI0906068 A2	
		PL 2379977 T3	
US 2014/0262156 A1	18 September 2014	(Family: none)	
EP 2975350 A1	20 January 2016	DE 102014108890 A1	
		PL 2975350 T3	
		TR 201908760 T4	
CN 101963472 A	02 February 2011	(Family: none)	
CN 110726325 A	24 January 2020	(Family: none)	

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Patent documents cited in the description

- JP 58158496 A **[0004]**