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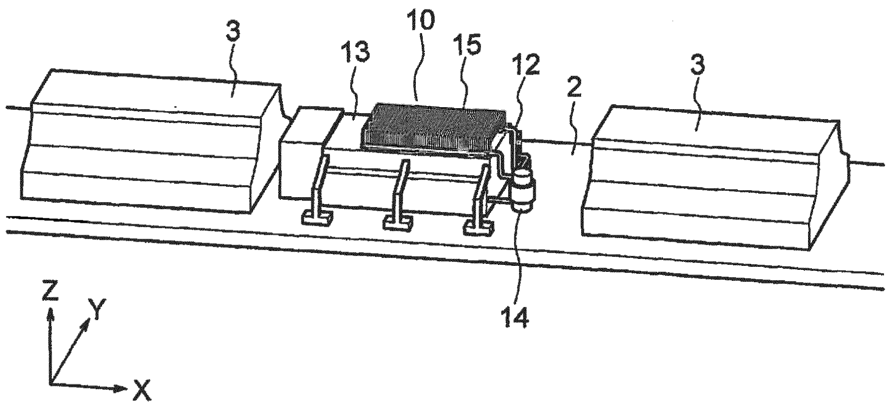
(54) TRANSFORMER FOR VEHICLE

(57) A traction transformer (10), which is to be installed on a roof (2) of a vehicle (1), includes: a main pipe (12), which forms a circulation passage for refrigerant; a transformer tank (13), which is arranged midway of the circulation passage, and is configured to accommodate a winding wire and store the refrigerant; a circulation pump (14), which is arranged midway of the circulation passage, and is configured to circulate the refrigerant in the circulation passage; and a cooler (15), which is arranged midway of the circulation passage and arranged on an upper surface of the transformer tank (13), and is configured to cool the refrigerant by heat exchange with air through use of traveling wind generated by traveling of the vehicle (1). The cooler (15) includes: a cooling-pipe mechanism, which is formed of a plurality of cooling pipes, and is arranged in a Z direction from the upper surface of the transformer tank (13); an inlet header (16a), which is configured to allow the refrigerant to flow into the cooling-pipe mechanism from the circulation pump side; and an outlet header (16b), which is configured to allow the refrigerant having flowed through the cooling-pipe mechanism to flow out to the transformer tank (13) side.

FIG. 3



EP 3 514 812 A1

Description

Technical Field

[0001] This invention relates to a traction transformer which is to be installed on a roof of a vehicle, in particular, a traction transformer which includes a cooler configured to cool cooling medium stored in a transformer tank through use of traveling wind generated by traveling of a vehicle.

Background Art

[0002] Devices such as an air conditioner, an exchanger, a controller, and a transformer, which are to be mounted to a vehicle, generate a large amount of heat during operations, and hence cooling of the devices is required. Methods of cooling those devices mainly include a forcible air-cooling method using a blower and a traveling-wind self-cooling method using traveling wind generated by traveling of a vehicle. In recent years, in view of advantages such as power saving and reduction of noise, the traveling-wind self-cooling method attracts attention.

[0003] As a cooler for a vehicle employing the traveling-wind self-cooling method, in consideration of ease of manufacture and ease of maintenance, a cooler including heat rejection pipes, which each have a U-shape and are arrayed in a plurality of stages, is employed in many cases (see, e.g. Patent Literature 1). Such a cooler includes a plurality of heat rejection pipes to increase an area for heat exchange with cooling wind and thereby secure high heat-rejection performance.

[0004] The size of the cooler differs depending on an installation location thereof and maximum heat generation amounts of the devices. For example, in a traveling-wind self-cooling method applied to an underfloor-arrangement-type onboard transformer in which the traveling wind is relatively easily guided to the cooler, a cooler volume of about 0.5 m^3 and a wind-guiding distance of about 1 m for guiding wind are required.

[0005] As a method of reducing the cooler volume for the traveling-wind self-cooling method, for example, there has been proposed a cooler using fin tubes (see, for example, Patent Literature 2). Such cooler includes heat rejection pipes each having a plurality of fins mounted thereto, and a heat rejection area per unit volume can be increased.

[0006] However, a measure against clogging between fins is required, with the result that ease of maintenance is degraded. Moreover, in addition to the ease of maintenance, manufacturing cost may also be a hindrance for such cooler. Thus, such cooler is not widely available at present.

List of Citations

Patent Literature

[0007]

[PTL 1] JP 59-84816 U
[PTL 2] JP 2007-273777 A

Summary of the Invention

Technical Problem

[0008] In a low-floor vehicle which is widely available in Europe and other regions, an underfloor installation space for devices is small, and hence the devices such as the air conditioner, the exchanger, the controller, and the transformer cannot be installed under a floor. Therefore, those devices are installed on a roof. When a traction transformer employing the traveling-wind self-cooling method is to be installed on a roof around which devices are closely arranged, there is an influence of separation of traveling wind around the traction transformer.

[0009] Therefore, in order to guide the traveling wind flowing at high flow velocity to the cooler, there is required a wind-guiding distance which is sufficiently larger as compared to the case of the underfloor installation. As a result, there arises a problem in that it is difficult to reduce the installation space for installation of the traction transformer on the roof of the vehicle.

[0010] This invention has been made to solve the problems described above, and has an object to obtain a traction transformer which is capable of achieving efficient cooling through use of traveling wind generated by traveling of a vehicle while reducing an installation space for installation on a roof of a vehicle.

Solution to the Problem

[0011] According to one embodiment of the present invention, there is provided a traction transformer, which is to be installed on a roof of a vehicle, including: a main pipe, which forms a circulation passage for refrigerant; a transformer tank, which is arranged midway of the circulation passage, and is configured to accommodate a winding wire and store the refrigerant; a circulation pump, which is arranged midway of the circulation passage, and is configured to circulate the refrigerant in the circulation passage; and

a cooler, which is arranged midway of the circulation passage and on an upper surface of the transformer tank, and is configured to cool the refrigerant by heat exchange with air,

wherein the vehicle has an X direction corresponding to a length direction of the vehicle, a Y direction corresponding to a vehicle width direction of the vehicle, and a Z direction corresponding to a height direction of the vehicle, and wherein the cooler includes: a cooling-pipe mechanism, which is formed of a plurality of cooling pipes, and is arranged in the Z direction from the upper surface of the transformer tank; an inlet header, which is configured to allow the refrigerant to flow into the cooling-pipe mechanism from the circulation pump side; and an outlet header, which is configured to allow the refrigerant having flowed through the cooling-pipe mechanism to flow out to the transformer tank side.

Advantageous Effects of the Invention

[0012] According to this invention, it is possible to obtain the traction transformer which is capable of achieving efficient cooling through use of traveling wind generated by traveling of the vehicle while reducing an installation space for installation on the roof of the vehicle.

Brief Description of the Drawings

[0013]

- FIG. 1 is a top view for illustrating a railway vehicle including a traction transformer according to a first embodiment of this invention, which is installed on a roof.
- FIG. 2 is a side view for illustrating the railway vehicle including the traction transformer according to the first embodiment of this invention, which is installed on the roof.
- FIG. 3 is an enlarged perspective view for illustrating a periphery of the traction transformer which is installed on the railway vehicle of FIG. 1 and FIG. 2.
- FIG. 4 is a top view of the traction transformer of FIG. 3.
- FIG. 5 is a side view of the traction transformer of FIG. 3.
- FIG. 6 is a sectional view taken along the line A-A' of FIG. 5 as seen in the direction indicated by the arrows.
- FIG. 7 is an explanatory view for illustrating a flow of traveling wind on a rear side of a peripheral device in an advancing direction on the roof of the railway vehicle in the first embodiment of this invention.
- FIG. 8 is a contour diagram for illustrating, in vehicle cross section, a wind velocity on the rear side of the peripheral device in the advancing direction on the roof of the railway vehicle in the first embodiment of this invention.
- FIG. 9 is a perspective view for illustrating a cooler in the first embodiment of this invention.
- FIG. 10 is a perspective view for illustrating a cooler in a second embodiment of this invention.
- FIG. 11 is a top sectional view of an intermediate header in the second embodiment of this invention.
- FIG. 12 is a perspective view for illustrating a cooler in a third embodiment of this invention.
- FIG. 13 is a rear perspective view of the cooler of FIG. 12.
- FIG. 14 is a sectional view for illustrating an inlet-side cooling-pipe group, an outlet-side cooling-pipe group, and a cooling-pipe group in a fourth embodiment of this invention.

Description of Embodiments

[0014] Now, a traction transformer according to exemplary embodiments of this invention is described with reference to the accompanying drawings. In the illustration of the drawings, the same components or corresponding components are denoted by the same reference symbols, and the overlapping description thereof is herein omitted.

First Embodiment

[0015] FIG. 1 is a top view for illustrating a railway vehicle 1 including a traction transformer 10 according to a first embodiment of this invention, which is installed on a roof 2. FIG. 2 is a side view for illustrating the railway vehicle including the traction transformer 10 according to the first embodiment of this invention, which is installed on the roof 2. FIG. 3 is an enlarged perspective view for illustrating a periphery of the traction transformer 10 which is installed on the railway vehicle 1 of FIG. 1 and FIG. 2. FIG. 4 is a top view of the traction transformer 10 of FIG. 3. FIG. 5 is a side view of the traction transformer 10 of FIG. 3.

[0016] In the following description, the railway vehicle 1 is simply referred to as "vehicle 1", and the traction transformer 10 is simply referred to as "transformer 10". For convenience of description, a length direction of the vehicle 1, that is, an advancing direction of the vehicle 1 is referred to as "X direction". Moreover, a vehicle width direction of the vehicle 1 is referred to as "Y direction", and a height direction of the vehicle is referred to as "Z direction". That is, the vehicle 1 can travel in both a +X direction and a -X direction. A +Z direction corresponds to the roof 2 side, and a -Z direction corresponds to a floor side.

[0017] The transformer 10 includes a winding wire 11, a main pipe 12, a transformer tank 13, a circulation pump 14, and a cooler 15. The transformer 10 is installed on the roof 2 of the vehicle 1. Moreover, peripheral devices 3 such as a converter, a controller, and an air conditioner are installed on the roof 2 in the +X direction and the -X direction of the transformer 10.

[0018] The winding wire 11 is accommodated in the transformer tank 13. The main pipe 12 forms a circulation passage for refrigerant. The transformer tank 13 is arranged midway of the circulation passage formed of the main pipe 12, and is configured to accommodate the winding wire 11 and store the refrigerant inside thereof.

The transformer tank 13 is installed at the center in the Y direction on the roof 2 of the vehicle 1.

[0019] The circulation pump 14 is arranged midway of the circulation passage formed of the main pipe 12, and is configured to circulate the refrigerant in the circulation passage. The circulation pump 14 is installed in the X direction of the transformer tank 13.

[0020] The cooler 15 is arranged midway of the circulation passage formed of the main pipe 12, and is configured to cool the refrigerant by heat exchange with air, specifically, by heat exchange with traveling wind generated at the time of traveling of the vehicle 1. Moreover, the cooler 15 is installed on an upper surface of the transformer tank 13, that is, on a +Z direction surface. An inlet side of the cooler 15 is connected to an inlet-side pipe 12a forming the main pipe 12, and an outlet side of the cooler 15 is connected to an outlet-side pipe 12b forming the main pipe 12.

[0021] The transformer tank 13 is a box having a rectangular parallelepiped shape. The transformer tank 13 accommodates the winding wire 11 inside thereof and is made of metal such as steel or aluminum. A surface of the transformer tank 13 has coating for prevention of corrosion, and has, for example, a bush for connection of an electric wire. Moreover, insulating oil is generally used as refrigerant. In particular, silicone oil having high noncombustibility or ester oil being advantageous in environment is used as refrigerant for vehicles.

[0022] Next, with reference to FIG. 6 to FIG. 8, further description is made of the arrangement of the transformer 10 on the roof 2. FIG. 6 is a sectional view taken along the line A-A' of FIG. 5 as seen in the direction indicated by the arrows. FIG. 7 is an explanatory view for illustrating a flow of traveling wind on a rear side of the peripheral device 3 in the advancing direction on the roof 2 of the railway vehicle 1 in the first embodiment of this invention. FIG. 8 is a contour diagram for illustrating, in vehicle cross section, a wind velocity on the rear side of the peripheral device 3 in the advancing direction on the roof 2 of the railway vehicle 1 in the first embodiment of this invention.

[0023] In the vehicle 1, as indicated by the broken line of FIG. 6, a vehicle body cross section of the vehicle 1, that is, a Y-Z cross section has limit values in the Y direction and the Z direction, that is, a rolling stock gauge 4 defined therefor. That is, a cross section of the vehicle 1 is required to be provided within the range of the rolling stock gauge 4. The rolling stock gauge 4 is a reference that is defined for avoiding interference between a vehicle body and a construction provided along a railway track. In relation to construction of tunnels, in many cases, the vehicle 1 has such a shape that an upper side of the roof 2, that is, the +Z direction side of the roof 2 is narrow.

[0024] A large number of devices are mounted to the vehicle 1, and hence it is required that a limited installation area be efficiently used. Therefore, as illustrated in FIG. 6, in many cases, the peripheral device 3 is designed so as to project to a maximum dimension falling within the rolling stock gauge 4.

[0025] In order to supply an overhead wiring voltage exceeding 20 000 Volt to a main circuit, the transformer 10 utilizes the principle of electromagnetic induction to step down the voltage. Moreover, the outer dimensions of the transformer 10 are determined based on the size of the winding wire 11, which is determined based on a frequency of overhead wiring power and a conversion efficiency of the transformer 10.

[0026] As mentioned above, the winding wire 11 is accommodated in the transformer tank 13 having the rectangular parallelepiped shape. For example, consideration is made of the case in which the rolling stock gauge 4 has a trapezoidal shape as illustrated in FIG. 6. In this case, when the transformer tank 13 has the rectangular parallelepiped shape, a space in which the devices can be arranged is defined by the upper surface side, that is, the +Z direction side of the transformer tank 13 and the side surface sides, that is, the +Y direction side and the -Y direction side of the transformer tank 13. However, in many cases, the main pipe 12 and a support structure body are arranged on the side surface sides of the transformer tank 13.

[0027] In FIG. 7, schematic illustration is given of a state in which a traveling wind 5 is separated by the peripheral device 3 installed on the roof 2 of the vehicle 1. It is assumed that the traveling wind 5 flows in the -X direction. The traveling wind 5 separated by the peripheral device 3 having a height h gradually approaches the roof 2 as proceeding toward downstream of a flow field, and is brought into contact with the roof 2 at a re-contact point 6.

[0028] In a case of an ideal two-dimensional flow field, a distance x from separation to re-contact is about seven times the height h of the peripheral device 3, that is, about 7h. Unlike the case of the arrangement under a floor of the vehicle 1 which is close to the ground, a vortex is less liable to be generated in the flow field on the roof 2 of the vehicle 1 being an open space. Therefore, in consideration of arranging the cooler on downstream of the peripheral device 3, a sufficient wind-guiding distance is required for obtaining traveling wind flowing at high flow velocity.

[0029] In FIG. 8, illustration is given of, for each x coordinate, a relationship between wind velocity distribution on the Y-Z plane after separation by the peripheral device 3 arranged so as to extend along the rolling stock gauge 4 and the inner side and the outer side of the rolling stock gauge 4. In FIG. 8, calculation is made based on h1 = 1 m and h2 = 0.6 m on the rolling stock gauge 4.

[0030] In this case, the re-contact of the main stream does not proceed at the position of about 1 m after separation, and it can be seen that wind flowing at high wind velocity is obtained only in the vicinity of a boundary of the rolling stock gauge 4. Moreover, the roof 2 of the vehicle 1 has a complicated shape. Thus, the course of re-contact is not as simple as that on downstream of the step, but a stagnation region 7 is formed after separation. Therefore, when the transformer 10 is arranged close to the peripheral device 3, sufficient wind velocity required for cooling can be obtained only in a region in a periphery of the boundary of the rolling stock gauge 4.

[0031] An allowable device arrangement height on the roof 2 is about 1 m at maximum. When the transformer tank 13 has a height of 0.7 m, on the upper surface side of the transformer tank 13, a space having a height of about 0.3 m can be secured between the upper surface of the transformer tank 13 and the rolling stock gauge 4. This space is a space in which traveling wind flows at high velocity even when the transformer 10 is arranged close to the peripheral device 3. Therefore, when the cooler, which has hitherto been arranged separately, is arranged in this space, the wind-guiding distance can be minimized, and hence there is given a significant merit in view of the installation space of the transformer 10.

[0032] Therefore, in the first embodiment, through use of the space which is defined on the upper surface side of the transformer tank 13 and allows arrangement of the devices, the cooler 15 is installed on the upper surface of the transformer tank 13. Further, a structure of the cooler 15 is devised so that required cooling performance can be obtained.

[0033] Next, with reference to FIG. 9, further description is made of the structure of the cooler 15. FIG. 9 is a perspective view for illustrating the cooler 15 in the first embodiment of this invention.

[0034] The cooler 15 includes an inlet header 16a, an outlet header 16b, and a direct cooling-pipe group 18. The inlet header 16a is configured to allow the refrigerant to flow thereinto from the circulation pump 14 side. The outlet header 16b is configured to allow the refrigerant to flow out to the transformer tank side.

[0035] The direct cooling-pipe group 18 includes a plurality of cooling pipes 17, which are arranged so as to allow the refrigerant to flow out from the inlet header 16a and flow into the outlet header 16b. In the following description, a mechanism, which is formed of a group of a plurality of cooling pipes that form flow passages between the inlet header 16a and the outlet header 16b and are configured to cool the refrigerant flowing through the flow passages, is referred to as "cooling-pipe mechanism".

[0036] In the first embodiment, illustration is given of an example case in which the cooling-pipe mechanism includes the direct cooling-pipe group 18, which is formed of the plurality of cooling pipes 17 elongated in the Y direction and arrayed in a plurality of rows in the X direction and connects the inlet header 16a and the outlet header 16b to each other.

[0037] The inlet header 16a and the outlet header 16b have a longitudinal direction extending in the X direction and are installed on the transformer tank 13 while being separated from each other in the Y direction and being parallel to each other.

[0038] The direct cooling-pipe group 18 is formed of the plurality of cooling pipes 17, which each have a U-shape protruding in the +Z direction and are arrayed in a plurality of rows in the X direction. The cooling pipes 17 are provided in the Z direction (upper side) from the upper surface of the transformer tank 13. The cooling pipes 17 are elongated in the Y direction. In the first embodiment, as one example, six U-shaped cooling pipes 17 having different sizes are arranged on the Y-Z plane, and the rows each including the six U-shaped cooling pipes 17 are arrayed at a constant pitch along the X direction.

[0039] The six cooling pipes 17 of each of the rows forming the direct cooling-pipe group 18 have different heights in the Z direction and widths in the Y direction, but the flow passages thereof have the same sectional shape. For example, the number of arrays of the cooling pipes 17 and pitches thereof may suitably be changed. Moreover, it is only required that part of the cooling pipes 17 be arranged in the Z direction so as to be separated from the upper surface of the transformer tank 13. Thus, part of the cooling pipes 17 may be held in contact with the upper surface of the transformer tank 13.

[0040] In each of the cooling pipes 17, the refrigerant having been increased in temperature due to heat received from, for example, the winding wire 11 flows therethrough. Each of the cooling pipes 17 has one end connected to the inlet header 16a and another end connected to the outlet header 16b.

[0041] The rows of the direct cooling-pipe group 18 are arrayed in the X direction, and hence the inlet header 16a and the outlet header 16b each have a shape elongated in the X direction.

[0042] The inlet header 16a is connected to the circulation pump 14, receives the refrigerant supplied from the circulation pump 14, and distributes the refrigerant to the cooling pipes 17. The outlet header 16b is connected so as to gather the refrigerant having flowed through the cooling pipes 17 and return the gathered refrigerant to the transformer tank 13.

[0043] The six cooling pipes 17 forming each of the rows of the direct cooling-pipe group 18 each include a first bent portion, a second bent portion, and a coupling portion. The first bent portion is bent with respect to the inlet header 16a from the +Z direction toward the +Y direction side. The second bent portion is bent with respect to the outlet header 16b from the +Z direction toward the -Y direction side. The coupling portion couples the first bent portion and the second bent portion to each other in parallel with a horizontal plane.

[0044] The first bent portion and the second bent portion are perpendicularly connected to the inlet header 16a and the outlet header 16b, respectively. However, it is not always required that the first bent portion and the second bent portion be connected to the inlet header 16a and the outlet header 16b in such a manner. Moreover, the coupling portion is in parallel with the horizontal plane. However, it is not always required that the coupling portion be provided in such a manner. For example, the coupling portion may have a gentle arch shape.

[0045] Moreover, in the first embodiment, as one example, pipes each having a flat shape are used as the cooling pipes 17, and the flat surfaces thereof extend along the X direction. When the flat pipes are used as the cooling pipes 17 as described above, the cooling performance is improved. However, in consideration of performance and cost, circular pipes may be used as the cooling pipes 17.

[0046] A space is defined below the direct cooling-pipe group 18. That is, a gap is defined between the coupling portions of the cooling pipes 17 arranged on an innermost side of the rows and the upper surface of the transformer tank 13. As illustrated in FIG. 9, the coupling portions of the cooling pipes 17 extend along the Y direction. Therefore, the space defined below the rows of the direct cooling-pipe group 18 is a space which is opened so as to be elongated in the Y direction with respect to the Z direction. In the following description, the space defined below the cooling pipes 17 is referred to as "opening space 19".

[0047] The direct cooling-pipe group 18 is arranged at a high position on the upper surface of the transformer tank 13. Therefore, even when any other devices are arranged on the front and rear sides, the direct cooling-pipe group 18 can successfully cool the refrigerant through use of the traveling wind. Moreover, when the traveling wind is not given, that is, when the vehicle 1 stops, air heated by the cooling pipes 17 rises and is cooled by convection.

[0048] However, the opening space 19 is defined below the rows of the direct cooling-pipe group 18. Therefore, air is more likely to flow into the space below the direct cooling-pipe group 18 from the outside of the cooler 15, and hence cooling by the convection is also successfully performed. Further, cooling from the upper surface of the transformer tank 13 can also be performed.

[0049] It is only required that the cooler 15 have a configuration in which most of the cooling pipes 17 are arranged on the upper surface side of the transformer tank 13. The extending direction of the cooling pipes 17 may suitably be changed. Moreover, as mentioned above, when the direct cooling-pipe group 18 has the configuration in which the opening space 19 is defined and opened so as to be elongated in the Y direction with respect to the Z direction, the traveling wind is more likely to flow into the space defined between the direct cooling-pipe group 18 and the transformer tank 13, and in particular, the cooling performance of the cooler 15 is improved.

[0050] Moreover, there is given the configuration in which the inlet header 16a and the outlet header 16b are both installed on the transformer tank 13. However, at least one of the inlet header 16a and the outlet header 16b may be arranged on the side of the transformer tank 13, that is, in the +Y direction or the -Y direction. Moreover, at least one of the first bent portion and the second bent portion of each of the cooling pipes 17 may be arranged on the side of the transformer tank 13.

[0051] As described above, according to the first embodiment, in the traction transformer which is to be installed on the roof of the vehicle, the cooler having a configuration capable of cooling the refrigerant by heat exchange with air is provided on the upper surface of the transformer tank which is configured to accommodate the winding wire and store the refrigerant.

[0052] Moreover, the cooler includes: the cooling-pipe mechanism, which is formed of the plurality of cooling pipes, and is arranged in the Z-direction from the upper surface of the transformer tank; the inlet header, which is configured to allow the refrigerant to flow into the cooling-pipe mechanism from the circulation pump side; and the outlet header, which is configured to allow the refrigerant having flowed through the cooling-pipe mechanism to flow out to the transformer tank side. In the first embodiment, as a specific configuration of such cooling-pipe mechanism, an example is given of the cooling-pipe mechanism including the direct cooling-pipe group including a plurality of cooling pipes, which are arranged so as to allow the refrigerant to flow out from the inlet header and flow into the outlet header and are elongated in the Y direction and arrayed in a plurality of rows in the X direction.

[0053] As described above, even when the traction transformer is arranged close to the peripheral device, through the arrangement of the cooler in the space of the upper surface of the transformer tank corresponding to the space through which the traveling wind flows at high velocity, the wind-guiding distance can be minimized, and the installation space for the traction transformer can be reduced. Moreover, there is no need to use, for example, a fan for cooling. Therefore, power consumption can be reduced, and a significant effect can be attained also in terms of reduction of noise.

Second Embodiment

[0054] In a second embodiment of this invention, description is made of the transformer 10 including a cooler 15A having a configuration different from that of the cooler 15 in the first embodiment. In the second embodiment, description of the features which are the same as those of the first embodiment is omitted, and features which are different from those of the first embodiment are mainly described.

[0055] FIG. 10 is a perspective view for illustrating the cooler 15A in the second embodiment of this invention. The cooler 15A includes the inlet header 16a, the outlet header 16b, an intermediate header 20, an inlet-side cooling-pipe group 21a, and an outlet-side cooling-pipe group 21b. The inlet header 16a is configured to allow refrigerant to flow thereinto from the circulation pump 14 side. The outlet header 16b is configured to allow the refrigerant to flow out to the transformer tank side. The intermediate header 20 is arranged between the inlet header 16a and the outlet header 16b.

[0056] The inlet-side cooling-pipe group 21a is arranged so as to allow the refrigerant to flow out from the inlet header 16a and flow into the intermediate header 20. The outlet-side cooling-pipe group 21b is arranged so as to allow the refrigerant, which has once been gathered, to flow out from the intermediate header 20 and then flow into the outlet header 16b. In the second embodiment, illustration is given of an example case in which the cooling-pipe mechanism includes the inlet-side cooling-pipe group 21a connected to the inlet header 16a and the outlet-side cooling-pipe group 21b connected to the outlet header 16b.

[0057] The inlet header 16a, the inlet-side cooling-pipe group 21a, the intermediate header 20, the outlet-side cooling-pipe group 21b, and the outlet header 16b are connected in series. The intermediate header 20 connecting the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b is configured to mix inside thereof the refrigerant having flowed into the intermediate header 20 from the inlet-side cooling-pipe group 21a, and allow the refrigerant to flow out to the outlet-side cooling-pipe group 21b while the refrigerant is re-distributed.

[0058] The inlet-side cooling-pipe group 21a includes a plurality of cooling pipes 17 arrayed in a plurality of rows in the X direction. Similarly, the outlet-side cooling-pipe group 21b includes a plurality of cooling pipes 17 arrayed in a plurality of rows in the X direction. Specifically, the inlet-side cooling-pipe group 21a is formed of the cooling pipes 17 arrayed in a plurality of rows at a constant pitch in the X direction. The plurality of rows of the cooling pipes 17 each include six cooling pipes 17.

[0059] The six cooling pipes 17 are arranged on the Y-Z plane, have different sizes, and each have a U-shape protruding in the +Z direction. Similarly, the outlet-side cooling-pipe group 21b is formed of the cooling pipes 17 arrayed in a plurality of rows at a constant pitch in the X direction. The plurality of rows of the cooling pipes 17 each include six cooling pipes 17. The six cooling pipes 17 are arranged on the Y-Z plane, have different sizes, and each have a U-shape protruding in the +Z direction.

[0060] The inlet header 16a is connected to the circulation pump 14 side, that is, to the inlet-side pipe 12a. The refrigerant having been increased in temperature due to heat received from, for example, the winding wire 11 flows into the inlet header 16a through the circulation pump 14. The inlet header 16a has a shape elongated in the X direction.

[0061] The outlet header 16b is connected to the outlet-side pipe 12a to return the refrigerant, which has been decreased in temperature as compared to the refrigerant inside the inlet header 16a, to the transformer tank 13. The outlet header 16b has a shape elongated in the X direction.

[0062] The intermediate header 20 is installed between the inlet header 16a and the outlet header 16b, and is arranged on the X-Y plane which is the same as the plane on which the inlet header 16a and the outlet header 16b are arranged. The intermediate header 20 has a shape elongated in the X direction. The inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b are located on the upper surface side of the transformer tank 13.

[0063] The inlet-side cooling-pipe group 21a is arranged at the -Y direction end in the Y direction, and the outlet-side cooling-pipe group 21b is arranged at the +Y direction end in the Y direction. That is, for example, when it is assumed that the inlet-side cooling-pipe group 21a is arranged on the right side of the drawing sheet with respect to the X direction, the outlet-side cooling-pipe group 21b is arranged on the left side of the drawing sheet with respect to the X direction. It is preferred that the intermediate header 20 be located on the upper surface of the transformer tank 13.

[0064] When the cooler 15A is arranged on the upper surface of the transformer tank 13, in order to allow the cooler 15A to be provided within the rolling stock gauge 4, the allowable height in the Z direction is about 0.3 m, and hence limitation on the height is strict. However, in the Y direction and the X direction which are parallel to the upper surface of the transformer tank 13, as a space for arranging the cooler 15, for example, a length of about 1 m in the Y direction and a length of about 2.5 m in the X direction can be secured. With this, the cooler 15A can be arranged with a relatively sufficient space.

[0065] The vehicle 1 requires a large amount of power at the time of acceleration during traveling, and a large amount of current flows through the winding wire 11 of the transformer 10. Therefore, the heat generation amount of the transformer 10 increases. Meanwhile, also when the vehicle is stopped, power is required for air conditioners and illumination devices. Thus, the transformer 10 generates heat even though the heat generation amount is not as large as that given during the traveling of the vehicle 1. Therefore, cooling of the transformer 10 is required not only during traveling of the vehicle but also when the vehicle is stopped.

[0066] When the vehicle is stopped, the traveling wind cannot be obtained. Therefore, it is required that a large number of cooling pipes 17 be arranged on the X-Y plane to increase the heat rejection area. However, when the number of cooling pipes 17 to be arranged in the X direction is excessively increased, pressure loss that may occur when the traveling wind 5 obtained during traveling of the vehicle passes through the cooler 15A in the X direction increases.

[0067] Therefore, the wind cannot flow into the cooler 15A. That is, in order to allow the cooler 15A to obtain high cooling performance during the traveling of the vehicle, it is required that a large number of cooling pipes 17 be arranged on the Y-Z cross section exposed to the traveling wind 5 during the traveling of the vehicle.

[0068] When the cooling pipes 17 are formed into the U-shape, there are less number of bent parts, and ease of processing is excellent. Thus, the manufacturing cost can be reduced. However, the space on the upper surface of the transformer tank 13 is a flat space which is elongated in the horizontal direction, that is, elongated in the X direction and the Y direction. Therefore, as in the case of the cooler 15 illustrated in FIG. 9, when the large opening space 19 is defined at the center portion of the cooler 15, there is a possibility that the cooling efficiency per unit volume of the cooler cannot be improved.

[0069] It is also possible to use, for example, W-shaped cooling pipes in order to improve the cooling efficiency of the cooler through arrangement of the cooling pipes also in the opening space 19. However, in this case, bending of the pipes becomes more complicated, with the result that the manufacturing cost drastically increases.

[0070] Therefore, in the second embodiment, as illustrated in FIG. 10, the intermediate header 20 is used to form the cooler 15A with the inlet-side cooling-pipe group 21a provided so as to allow the refrigerant to flow into the intermediate header 20 from the inlet header 16a and the outlet-side cooling-pipe group 21b provided so as to allow the refrigerant to flow out from the intermediate header 20 and flow into the outlet header 16b.

[0071] With such a configuration of the cooler 15A, in the flat space elongated in the horizontal direction on the upper surface of the transformer tank 13, a large number of cooling pipes 17 can be arrayed on a passage plane of the traveling wind 5, that is, the Y-Z plane. As a result, the cooler having high heat-rejection performance per unit volume can be obtained at low cost.

[0072] Moreover, when the cooler 15 illustrated in FIG. 9 is arranged so as to fill the flat space elongated in the horizontal direction on the upper surface of the transformer tank 13, the pipe length of the cooling pipes 17 in the Y direction becomes larger. In a region 31a illustrated in FIG. 9 close to the inlet header 16a, the temperature of the refrigerant flowing inside the cooling pipes 17 is high.

[0073] Therefore, a sufficient temperature difference with respect to outside air can be obtained, thereby being capable of obtaining high heat-rejection performance in accordance with the flow velocity of the traveling wind 5. Moreover, when the pipe length of the cooling pipes 17 in the Y direction is large, heat rejection proceeds midway of the flow passage, and hence the temperature of the refrigerant decreases as the refrigerant approaches the outlet header 16b. Therefore, in a region 31b close to the outlet header 16b, as compared to the region 31a, a thermal flux with the outside air is reduced.

[0074] Meanwhile, in a region 32a and a region 32b corresponding to downstream of the flow field of the traveling wind 5, first of all, the traveling wind 5 is less likely to flow thereinto. Thus, even in the region close to the inlet header 16a, the thermal flux with the outside air is small. Therefore, even in a periphery of the outlet header 16b, the temperature of the refrigerant does not significantly decrease from the temperature in a periphery of the inlet header 16a.

[0075] In the second embodiment, the intermediate header 20 is arranged between the refrigerant flow passages of the inlet header 16a and the outlet header 16b. With such a configuration, the refrigerant flows into the plurality of cooling pipes 17 from the inlet header 16a, and the refrigerant having flowed through the region 31 in which the heat rejection has proceeded due to exposure to the traveling wind 5 and the refrigerant having flowed through the region 32a that is less decreased in temperature without inflow of the traveling wind 5 can be mixed once in the intermediate header 20.

[0076] Moreover, through mixing of the refrigerant having flowed through the downstream of the flow field of the traveling wind 5 with less decrease in temperature and the refrigerant having flowed through upstream of the flow field of the traveling wind 5 in which the decrease in temperature has proceeded, the temperature of the refrigerant flowing through the region 31b exposed to the traveling wind 5 flowing at high flow velocity can be maintained higher as compared to the case in which the intermediate header 20 is not provided. Therefore, as compared to the case in which the intermediate header 20 is not provided, an overall heat rejection amount of the cooler can be set higher.

[0077] FIG. 11 is a top sectional view of the intermediate header 20 in the second embodiment of this invention. A flow straightening plate 22 is arranged in the X direction in the intermediate header 20 so as to partition the inlet-side cooling-pipe group 21a connected to the inlet header 16a and the outlet-side cooling-pipe group 21b connected to the outlet header 16b. A +X direction end of the flow straightening plate 22 is connected to a header end surface of the intermediate header 20, and a -X direction end of the flow straightening plate 22 is not connected to a header end surface of the intermediate header 20.

[0078] As illustrated in FIG. 11, a flow passage cross section of each of the cooling pipes 17 has a flat shape with a large diameter in the X direction. Thus, while a surface area of the cooling pipes 17 is increased, pressure loss caused when the traveling wind 5 passes through the cooler 15A can be reduced.

[0079] The refrigerant having flowed into the intermediate header 20 from the inlet header 16a, which is arranged on the -Y direction side of the intermediate header 20, through the inlet-side cooling-pipe group 21a, as indicated by the illustrated flow direction 23, flows in the -X direction through the intermediate header 20 and turns back at the -X end. Then, while flowing through a region 33c of the intermediate header 20 in the +X direction, the refrigerant flows into the outlet header 16b through the outlet-side cooling-pipe group 21b.

[0080] The refrigerant flowing into a region 33a of the intermediate header 20 from the inlet header 16a through the inlet-side cooling-pipe group 21a is exposed to the traveling wind 5 during traveling of the vehicle. Therefore, the temperature of the refrigerant is lower than the temperature of the refrigerant flowing into a region 33b in which the heat exchange with the traveling wind 5 does not proceed. However, in the intermediate header 20, the refrigerant having been delivered from the inlet header 16a is mixed once, and hence equalization of the temperature of the refrigerant is promoted in the region 33c.

[0081] For convenience, description is made of the example case with the mode in which the +X direction end of the flow straightening plate 22 is connected to the header end surface of the intermediate header 20. However, the mode of the flow straightening plate 22 is not limited to this. Any other mode may be employed as long as the equalization of the temperature of the refrigerant can be promoted through mixing of the refrigerant in the intermediate header 20.

[0082] For example, even in the mode in which the -X direction end of the flow straightening plate 22 is connected to the header end surface and in which the +X direction end of the flow straightening plate 22 is not connected to the header end surface, the same effect as that of the mode described above can be attained. Moreover, for example, even in a mode in which both the +X direction end and the -X direction end of the flow straightening plate 22 are connected to the header end surfaces and in which an intermediate portion of the flow straightening plate 22 is separated, the same effect as that of the mode described above can be attained.

[0083] As described above, the intermediate header 20 includes the flow straightening plate 22 configured to promote the equalization of the temperature of the refrigerant in the intermediate header 20.

[0084] According to the second embodiment, the cooling-pipe mechanism of the cooler includes the inlet-side cooling-pipe group connected to the inlet header and the outlet-side cooling-pipe group connected to the outlet header. The inlet-side cooling-pipe group and the outlet-side cooling-pipe group are connected through intermediation of the intermediate header. With this configuration, the same effect as that of the first embodiment can be attained.

[0085] Further, through use of the intermediate header, a thin cooler including the plurality of cooling pipes arrayed in a plurality of rows in a distributed manner can be provided at low cost. Therefore, as compared to the first embodiment, the cooler can be more easily arranged in a narrow space on the upper surface of the transformer tank.

[0086] In the second embodiment, description is made of the example case with the cooler 15A in which the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b are connected through intermediation of the intermediate header 20. However, the cooling-pipe mechanism of the cooler 15A may include the direct cooling-pipe group which is directly connected from the inlet header 16a to the outlet header 16b without the intermediate header 20. Moreover, the flow straightening plate 22 is provided inside the intermediate header 20, and hence the effect of equalizing the temperature of the refrigerant is excellent.

[0087] However, as long as the space in which the refrigerant is mixed is defined, the effect of equalization can be attained to some extent even without the flow straightening plate 22. Further, in place of the flow straightening plate 22, there may be provided a structure for promoting mixing of the refrigerant such as a protrusion-and-recess structure or fins which may cause a turbulent flow in the refrigerant inside the intermediate header 20.

[0088] Moreover, the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b may be connected to each other through intermediation of a plurality of intermediate headers 20 arranged between the inlet header 16a and the outlet header 16b.

Third Embodiment

[0089] In a third embodiment of this invention, description is made of the transformer 10 including a cooler 15B having a configuration different from that of the cooler 15 in the first embodiment and that of the cooler 15A in the second embodiment. In the third embodiment, description of the features which are the same as those of the first and second embodiments is omitted, and features which are different from those of the first and second embodiments are mainly described.

[0090] FIG. 12 is a perspective view for illustrating the cooler 15B in the third embodiment of this invention. FIG. 13 is a rear perspective view of the cooler 15B of FIG. 12.

[0091] The cooler 15B includes the inlet header 16a, the outlet header 16b, an upstream-side intermediate-header portion, a downstream-side intermediate-header portion, the inlet-side cooling-pipe group 21a, the outlet-side cooling-pipe group 21b, and a direct cooling-pipe group 24. The inlet header 16a is configured to allow the refrigerant to flow thereinto from the circulation pump 14 side. The outlet header 16b is configured to allow the refrigerant to flow out to the transformer tank side.

[0092] The upstream-side intermediate-header portion and the downstream-side intermediate-header portion are arrayed in the X direction between the inlet header 16a and the outlet header 16b. The inlet-side cooling-pipe group 21a is arranged so as to allow the refrigerant to flow out from the inlet header 16a and flow into each of the upstream-side intermediate-header portion and the downstream-side intermediate-header portion.

[0093] The outlet-side cooling-pipe group 21b is arranged so as to allow the refrigerant to flow out from each of the upstream-side intermediate-header portion and the downstream-side intermediate-header portion and flow into the outlet header 16b. The direct cooling-pipe group 24 is arranged so as to allow the refrigerant to flow out from the inlet header 16a and flow into the outlet header 16b.

[0094] The intermediate header in the third embodiment includes the upstream-side intermediate-header portion and the downstream-side intermediate-header portion which are arrayed in the X direction between the inlet header 16a and the outlet header 16b. The terms "upstream" and "downstream" of the upstream-side intermediate-header portion and the downstream-side intermediate-header portion correspond to upstream and downstream in the traveling direction, and do not correspond to upstream and downstream of the flow of the refrigerant.

[0095] The inlet-side cooling-pipe group 21a in the third embodiment includes an upstream-side relay cooling-pipe group connected to the upstream-side intermediate-header portion and a downstream-side relay cooling-pipe group connected to the downstream-side intermediate-header portion. Those two relay cooling-pipe groups forming the inlet-side cooling-pipe group 21a are each formed of the cooling pipes 17 arrayed in a plurality of rows at a constant pitch in the X direction.

[0096] The plurality of rows of the cooling pipes 17 each include six cooling pipes 17. The six cooling pipes 17 are arranged on the Y-Z plane, have different sizes, and each have a U-shape protruding in the +Z direction. A flow passage cross section of each of the cooling pipes 17 forming the inlet-side cooling-pipe group 21a has a flat shape having a diameter which is larger in the X direction.

[0097] Similarly, the outlet-side cooling-pipe group 21b includes an upstream-side relay cooling-pipe group connected to the upstream-side intermediate-header portion and a downstream-side relay cooling-pipe group connected to the downstream-side intermediate-header portion. Those two relay cooling-pipe groups forming the outlet-side cooling-pipe group 21b are each formed of the cooling pipes 17 arrayed in a plurality of rows at a constant pitch in the X direction. The plurality of rows of the cooling pipes 17 each include six cooling pipes 17.

[0098] The six cooling pipes 17 are arranged on the Y-Z plane, have different sizes, and each have a U-shape protruding in the +Z direction. A flow passage cross section of each of the cooling pipes 17 forming the inlet-side cooling-pipe group 21b has a flat shape having a diameter which is larger in the X direction. The inlet-side cooling-pipe group 21a is arranged at the -Y direction end in the Y direction, and the outlet-side cooling-pipe group 21b is arranged at the +Y direction end in the Y direction.

[0099] The direct cooling-pipe group 24 is formed of the plurality of cooling pipes 17, which are elongated in the Y direction and arrayed in a plurality of rows in the X direction. The direct cooling-pipe group 24 connects the inlet header 16a and the outlet header 16b to each other. Specifically, the direct cooling-pipe group 24 is formed of the cooling pipes 17 arrayed in a plurality of rows at a constant pitch along the X direction. The plurality of rows of the cooling pipes 17 each include six cooling pipes 17.

[0100] The six cooling pipes 17 are arranged on the Y-Z plane, have different sizes, and each have a U-shape protruding in the +Z direction. A flow passage cross section of each of the cooling pipes 17 forming the direct cooling-pipe group 24 has a flat shape having a diameter which is larger in the X direction.

[0101] The upstream-side intermediate-header portion is arranged at the +X direction end, and the downstream-side intermediate-header portion is arranged at the -X direction end. In the case of such arrangement relationship, the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b are arranged at each of the +X direction end and the -X direction end.

[0102] The direct cooling-pipe group 24 is arranged between the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b arranged at the X direction end, and the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b arranged at the -X direction end.

[0103] The upstream-side intermediate-header portion has a first space 25a for allowing the refrigerant to flow thereinto from the inlet-side cooling-pipe group 21a and a second space 25b for allowing the refrigerant to flow out to the outlet-side cooling-pipe group 21b. The downstream-side intermediate-header portion has a first space 26a for allowing the refrigerant to flow thereinto from the inlet-side cooling-pipe group 21a and a second space 26b for allowing the refrigerant to flow out to the outlet-side cooling-pipe group 21b.

[0104] Specifically, the upstream-side intermediate-header portion includes a header 25 and a partition plate 27. The partition plate 27 is configured to partition the inside of the header 25 into the first space 25a for allowing the refrigerant to flow thereinto from the inlet-side cooling-pipe group 21a and the second space 25b for allowing the refrigerant to flow out to the outlet-side cooling-pipe group 21b. Similarly, the downstream-side intermediate-header portion includes a header 26 and the partition plate 27.

[0105] The partition plate 27 is configured to partition the inside of the header 26 into the first space 26a for allowing the refrigerant to flow thereinto from the inlet-side cooling-pipe group 21a and the second space 26b for allowing the refrigerant to flow out to the outlet-side cooling-pipe group 21b. Among the cooling pipes 17 forming the inlet-side cooling-pipe group 21a, the plurality of cooling pipes 17 located at the +X direction end are connected to the first space 25a of the upstream-side intermediate-header portion, and the plurality of remaining cooling pipes 17 located at the -X direction end are connected to the first space 26a of the downstream-side intermediate-header portion.

[0106] Moreover, among the cooling pipes 17 forming the outlet-side cooling-pipe group 21b, the plurality of cooling pipes 17 located at the +X direction end are connected to the second space 25b of the upstream-side intermediate-header portion, and the plurality of remaining cooling pipes 17 located at the -X direction end are connected to the second space 26b of the downstream-side intermediate-header portion.

[0107] The cooler 15B further includes a first auxiliary pipe 28 and a second auxiliary pipe 29. The first auxiliary pipe 28 serves as a first flow passage for allowing the refrigerant to flow from the first space 25a of the upstream-side intermediate-header portion to the second space 26b of the downstream-side intermediate-header portion. The second auxiliary pipe 29 serves as a second flow passage for allowing the refrigerant to flow from the first space 26a of the downstream-side intermediate-header portion to the second space 25b of the upstream-side intermediate-header portion.

[0108] The partition plate 27 is arranged in each of the header 25 and the header 26 so as to partition in the Y direction and be elongated in the X direction. The partition plate 27 arranged in the header 25 partitions the space inside the header 25 into the first space 25a and the second space 25b.

[0109] The partition plate 27 arranged in the header 26 partitions the space inside the header 26 into the first space 26a and the second space 26b. The first auxiliary pipe 28 connects the first space 25a and the second space 26b to each other. The second auxiliary pipe 28 connects the first space 26a and the second space 25b to each other.

[0110] The refrigerant having flowed into the inlet header 16a from the inlet-side pipe 12a by the circulation pump 14 flows into the inlet-side cooling-pipe group 21a arranged at each of the +X direction end and the -X direction end and into the direct cooling-pipe group 24.

[0111] The refrigerant having flowed into the inlet-side cooling-pipe group 21a arranged at the +X direction end from the inlet header 16a flows into the first space 25a of the header 25. The refrigerant having flowed into the first space 25a flows into the second space 26b of the header 26 through the first auxiliary pipe 28. The refrigerant having flowed into the second space 26b flows into the outlet header 16b through the outlet-side cooling-pipe group 21b arranged at the - X direction end.

[0112] Meanwhile, the refrigerant having flowed into the inlet-side cooling-pipe group 21a arranged at the -X direction end from the inlet header 16a flows into the first space 26a of the header 26. The refrigerant having flowed into the first space 26a flows into the second space 25b of the header 25 through the second auxiliary pipe 29. The refrigerant having flowed into the second space 25b flows into the outlet header 16b through the outlet-side cooling-pipe group 21b arranged at the +X direction end.

[0113] When the cooling pipes 17 are arrayed in a plurality of stages in the X direction, pressure loss of the wind passage system of the cooler increases. As a result, there is a possibility that the traveling wind having flowed into the cooler from the +X direction does not reach the -X direction end of the cooler while maintaining sufficient wind velocity.

[0114] Therefore, in the third embodiment, the cooler 15B has a configuration in which only the cooling pipes 17 which are arranged at the X direction end and highly contribute to the heat rejection during traveling of the vehicle are densely arranged on the Y-Z plane. With such a configuration, as illustrated in FIG. 13, the opening space 19 is defined at the center portion of the cooler 15B.

[0115] Therefore, even when the cooling pipes 17 are arrayed in a plurality of stages in the X direction, the increase in pressure loss of the wind passage system of the cooler for the traveling wind can be suppressed. Moreover, the traveling wind can spread over the entirety of the cooler. With this, the heat-rejection performance of the cooler can be maximally brought out.

[0116] Moreover, the cooler 15B has the following configuration. That is, the refrigerant flow passage is provided between the first space 25a and the second space 26b through use of the first auxiliary pipe 28, and the refrigerant flow passage is provided between the first space 26a and the second space 25b through use of the second auxiliary pipe 29.

[0117] With such a configuration, the refrigerant having a high temperature can be exposed to the traveling wind flowing upstream of the flow field, which has not yet received heat from the refrigerant and has not been increased in temperature. As a result, the thermal flux from the refrigerant to the outside air can be increased, and hence high heat-rejection performance can be obtained in the cooler 15B installed in the limited space.

[0118] Description is made of the example case in which the two spaces are defined by partitioning the one space inside the intermediate header into two spaces through use of the partition plate 27. However, the same effect as that described above can be attained also when two spaces are defined through use of two separate headers without use of the partition plate 27.

[0119] In this case, the upstream-side intermediate-header portion and the downstream-side intermediate-header portion each include a first header and a second header arrayed in the Y direction. The first auxiliary pipe 28 allows the refrigerant to flow from the first header of the upstream-side intermediate-header portion to the second header of the downstream-side intermediate-header portion. The second auxiliary pipe 29 allows the refrigerant to flow from the first header of the downstream-side intermediate-header portion to the second header of the upstream-side intermediate-header portion.

[0120] In the third embodiment, description is made of the example case in which the cooler 15B includes, in addition to the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b, the direct coupling-pipe group 24 which is arranged so as to allow the refrigerant to flow out from the inlet header 16a and directly flow into the outlet header 16b.

[0121] However, all of the cooling pipe groups of the cooler 15B may be formed of only the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b. Moreover, the upstream-side intermediate-header portion and the downstream-side intermediate-header portion may form an integrated structure, and flow passages corresponding to the first auxiliary pipe 28 and the second auxiliary pipe 29 may be provided inside the structure.

[0122] According to the third embodiment, the cooling-pipe mechanism of the cooler includes the inlet-side cooling-pipe group connected to the inlet header and the outlet-side cooling-pipe group connected to the outlet header. The inlet-side cooling-pipe group connected to the inlet header includes the upstream-side relay cooling-pipe group connected to the upstream-side intermediate-header portion and the downstream-side relay cooling-pipe group connected to the downstream-side intermediate-header portion.

[0123] The outlet-side cooling-pipe group connected to the outlet header includes the upstream-side relay cooling-pipe group connected to the upstream-side intermediate-header portion and the downstream-side relay cooling-pipe group connected to the downstream-side intermediate-header portion.

[0124] With this, the same effect as that of the first embodiment and the second embodiment can be attained. Further, through the arrangement of the upstream-side intermediate-header portion at the +X direction end and the arrangement of the downstream-side intermediate-header portion at the -X direction end, as compared to the first embodiment and the second embodiment, the heat-rejection performance of the cooler can be more maximally brought out.

Fourth Embodiment

[0125] In a fourth embodiment of this invention, description is made of a case in which, in the cooler 15B of the third embodiment, a diameter in the X direction of each of the cooling pipes 17 forming the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b is set larger than a diameter in the X direction of each of the cooling pipes 17 forming the direct cooling-pipe group 24. In the fourth embodiment, description of the features which are the same as those of the first to third embodiments is omitted, and features which are different from those of the first to third embodiments are mainly described.

[0126] FIG. 14 is a sectional view for illustrating the inlet-side cooling-pipe group 21a, the outlet-side cooling-pipe group 21b, and the direct cooling-pipe group 24 in the fourth embodiment of this invention.

[0127] As illustrated in FIG. 14, the cooling pipes 17 forming each of the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b are equal in diameter in the Z direction but larger in diameter in the X direction with respect to the cooling pipes 17 forming the direct cooling-pipe group 24.

[0128] In the configuration of the cooler 15B in the third embodiment, there is a difference in pressure loss between the refrigerant flow passages, that is, between the flow passage for the refrigerant flowing from the inlet header 16a to the outlet header 16b through the header 25 and the header 26 and the flow passage for the refrigerant directly flowing from the inlet header 16a to the outlet header 16b.

[0129] Specifically, the flow passage for the refrigerant flowing from the inlet header 16a to the outlet header 16b through the header 25 and the header 26 has more bending portions in the flow passage as compared to the flow passage for the refrigerant directly flowing from the inlet header 16a to the outlet header 16b, with the result that the pressure loss increases.

[0130] When the pressure loss difference occurs between the refrigerant flow passages connected from the inlet header 16a to the outlet header 16b, a difference in flow rate of the refrigerant flowing through the cooling pipes 17 occurs, and hence unevenness in heat-rejection performance of the cooling pipes 17 becomes more conspicuous. As a result, the heat-rejection performance may be degraded. For the flow passages through which the refrigerant flows at significantly high flow velocity, an additional countermeasure related to the mechanical strength is also required.

[0131] A flow-passage sectional area of the cooling pipe having the U-shape is sensitive with respect to the pressure loss in the refrigerant flow passage. Therefore, when the flow-passage sectional area of each of the cooling pipes 17 forming the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b is set larger than the flow-passage sectional area of each of the cooling pipes 17 forming the direct cooling-pipe group 24, the pressure loss can be evenly set for the refrigerant flow passages. However, when the flow passage cross section for the traveling wind 5 is set narrow, the traveling wind 5 becomes less likely to flow into the cooler 15B.

[0132] Therefore, in the fourth embodiment, as illustrated in FIG. 14, without changing the flow-passage sectional area for the traveling wind 5, the diameter in the X direction of each of the cooling pipes 17 forming the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b is set larger than the diameter in the X direction of each of the cooling pipes 17 forming the direct cooling-pipe group 24. With such a configuration, without a hindrance to the flow of the traveling wind 5, the flow rate balance of the refrigerant flowing through the cooling pipes 17 can be adjusted.

[0133] Moreover, the increase in pressure loss in the refrigerant flow passages can be suppressed by setting the flow-passage sectional area of each of the first auxiliary pipe 28 and the second auxiliary pipe 29 to be larger than the flow-passage sectional area of each of the cooling pipes 17 forming the inlet-side cooling-pipe group 21a and the outlet-side cooling-pipe group 21b. As a result, degradation in flow rate balance of the refrigerant flowing through the cooling pipes 17 can be prevented.

[0134] According to the fourth embodiment, as compared to the configuration of the cooler in the third embodiment, the diameter in the X direction of each of the cooling pipes forming the inlet-side cooling-pipe group and the outlet-side cooling-pipe group is set larger than the diameter in the X direction of each of the cooling pipes forming the cooling-pipe group.

[0135] With this, without a hindrance to the flow of the traveling wind 5, the flow rate balance of the refrigerant flowing through the cooling pipes 17 can be adjusted.

[0136] Description is given of the first to fourth embodiments individually, but the configuration examples described respectively in the first to fourth embodiments can arbitrary be combined with each other.

Claims

1. A traction transformer, which is to be installed on a roof of a vehicle, comprising:

- a main pipe, which forms a circulation passage for refrigerant;
- a transformer tank, which is arranged midway of the circulation passage, and is configured to accommodate a winding wire and store the refrigerant;
- a circulation pump, which is arranged midway of the circulation passage, and is configured to circulate the refrigerant in the circulation passage; and
- a cooler, which is arranged midway of the circulation passage and on an upper surface of the transformer tank, and is configured to cool the refrigerant by heat exchange with air,
- wherein the vehicle has an X direction corresponding to a length direction of the vehicle, a Y direction corresponding to a vehicle width direction of the vehicle, and a Z direction corresponding to a height direction of the vehicle, and
- wherein the cooler includes:

  a cooling-pipe mechanism, which is formed of a plurality of cooling pipes, and is arranged in the Z direction from the upper surface of the transformer tank;
  an inlet header, which is configured to allow the refrigerant to flow into the cooling-pipe mechanism from the circulation pump side; and
  an outlet header, which is configured to allow the refrigerant having flowed through the cooling-pipe mechanism to flow out to the transformer tank side.

2. The traction transformer according to claim 1, wherein the cooling-pipe mechanism includes a direct cooling-pipe group, which includes a plurality of cooling pipes elongated in the Y direction and arrayed in a plurality of rows in the X direction and connects the inlet header and the outlet header to each other.

3. The traction transformer according to claim 1, wherein the cooling-pipe mechanism includes:

   an inlet-side cooling-pipe group connected to the inlet header; and
   an outlet-side cooling-pipe group connected to the outlet header, and wherein the cooler further includes an intermediate header which connects the inlet-side cooling-pipe group and the outlet-side cooling-pipe group to each other.

4. The traction transformer according to claim 3, wherein the inlet-side cooling-pipe group includes a plurality of cooling pipes arrayed in a plurality of rows in the X direction, and is arranged at a -Y direction end in the Y direction, and
   wherein the outlet-side cooling-pipe group includes a plurality of cooling pipes arrayed in a plurality of rows in the X direction, and is arranged at a +Y direction end in the Y direction.

5. The traction transformer according to claim 3 or 4, wherein the inlet header, the outlet header, and the intermediate header are arranged on the same X-Y plane.

6. The traction transformer according to any one of claims 3 to 5,
   wherein the intermediate header includes a flow straightening plate configured to promote equalization of temperature of the refrigerant inside the intermediate header.

7. The traction transformer according to any one of claims 1 to 6,
   wherein the flow passage cross section of each of the cooling pipes has a flat shape having a diameter which is larger in the X direction.

8. The traction transformer according to any one of claims 3 to 5,
   wherein the intermediate header includes an upstream-side intermediate-header portion and a downstream-side intermediate-header portion, which are arrayed in the X direction between the inlet header and the outlet header, and
   wherein the inlet-side cooling-pipe group includes:

   an upstream-side relay cooling-pipe group connected to the upstream-side intermediate-header portion; and
   a downstream-side relay cooling-pipe group connected to the downstream-side intermediate-header portion.

9. The traction transformer according to claim 8, wherein the outlet-side cooling-pipe group includes:

   an upstream-side relay cooling-pipe group connected to the upstream-side intermediate-header portion; and
   a downstream-side relay cooling-pipe group connected to the downstream-side intermediate-header portion.

10. The traction transformer according to claim 8 or 9, wherein the upstream-side intermediate-header portion is arranged at a +X direction end in the X direction, and

wherein the downstream-side intermediate-header portion is arranged at a -X direction end in the X direction.

11. The traction transformer according to any one of claims 8 to 10,
wherein the upstream-side intermediate-header portion and the downstream-side intermediate-header portion each include:

a first space for allowing the refrigerant to flow in from the inlet-side cooling-pipe group; and
a second space for allowing the refrigerant to flow out to the outlet-side cooling-pipe group, and
wherein the cooler further includes:

a first flow passage for allowing the refrigerant to flow from the first space in the upstream-side intermediate-header portion to the second space in the downstream-side intermediate-header portion; and
a second flow passage for allowing the refrigerant to flow from the first space in the downstream-side intermediate-header portion to the second space in the upstream-side intermediate-header portion.

12. The traction transformer according to any one of claims 8 to 10,
wherein the upstream-side intermediate-header portion and the downstream-side intermediate-header portion each include a first header and a second header which are arrayed in the Y direction, and
wherein the cooler includes:

a first flow passage for allowing the refrigerant to flow from the first header of the upstream-side intermediate-header portion to the second header of the downstream-side intermediate-header portion; and
a second flow passage for allowing the refrigerant to flow from the first header of the downstream-side intermediate-header portion to the second header of the upstream-side intermediate-header portion.

13. The traction transformer according to claim 11 or 12, wherein the flow-passage sectional area of each of the first flow passage and the second flow passage is larger than the flow-passage sectional area of each of the cooling pipes of the inlet-side cooling-pipe group and the outlet-side cooling-pipe group.

14. The traction transformer according to any one of claims 8 to 13,
wherein the cooling-pipe mechanism further includes a direct cooling-pipe group, which includes a plurality of cooling pipes elongated in the Y direction and arrayed in a plurality of rows in the X direction and connects the inlet header and the outlet header to each other.

15. The traction transformer according to claim 14,
wherein the flow passage cross section of each of the cooling pipes has a flat shape having a diameter which is larger in the X direction.

16. The traction transformer according to claim 15,
wherein the diameter of each of the cooling pipes of the inlet-side cooling-pipe group and the outlet-side cooling-pipe group in the X direction is larger than the diameter of each of the cooling pipes of the direct cooling-pipe group in the X direction.

17. The traction transformer according to any one of claims 1 to 16,
wherein the cooling pipes each have a U-shape.

FIG. 1

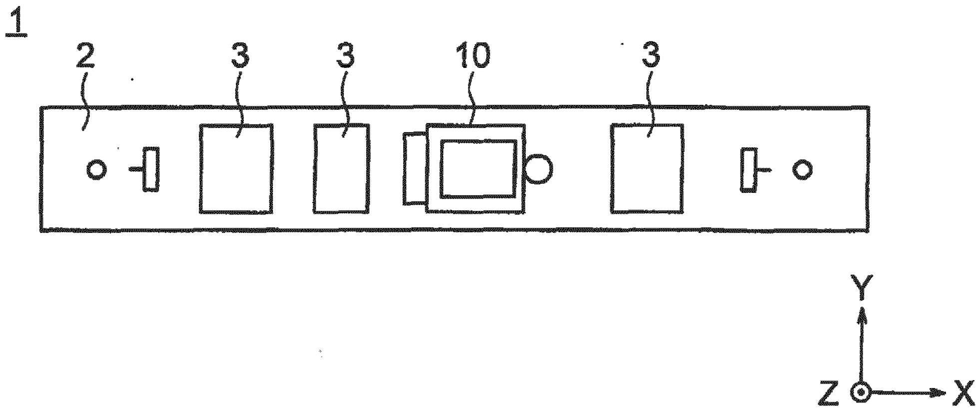


FIG. 2

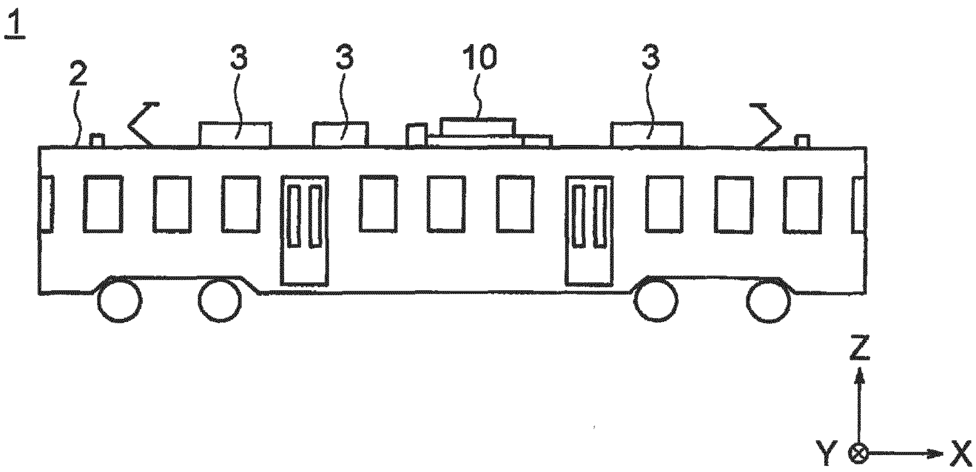


FIG. 3

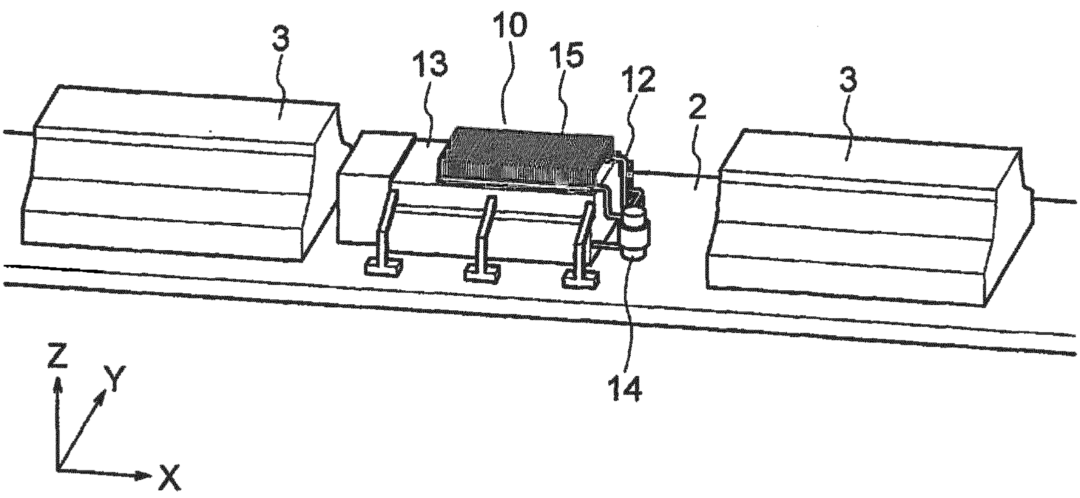


FIG. 4

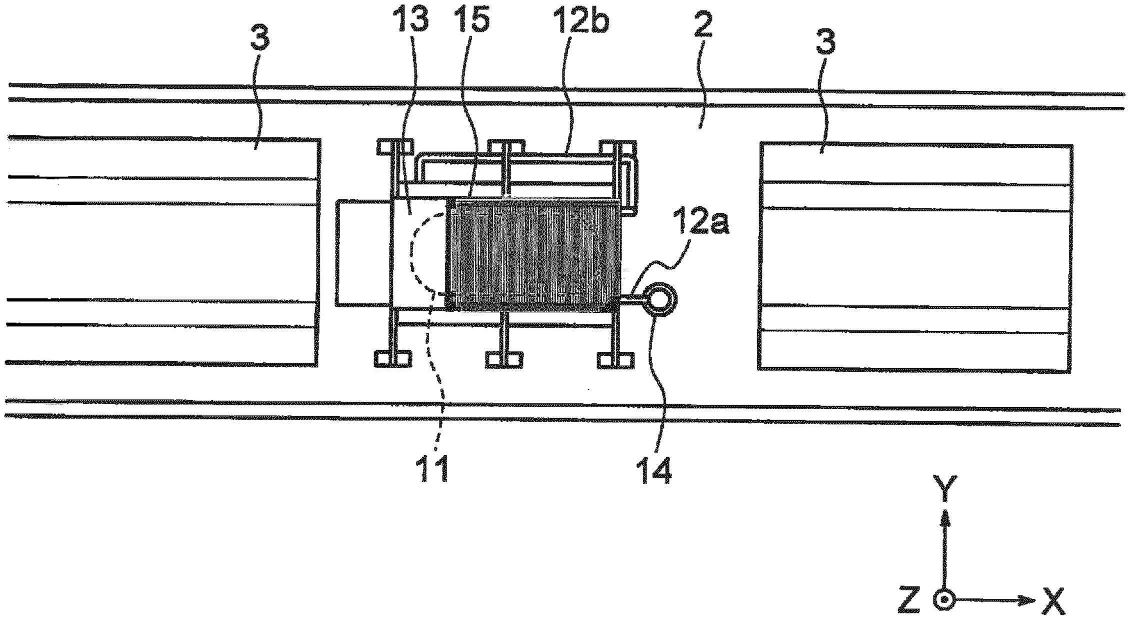


FIG. 5

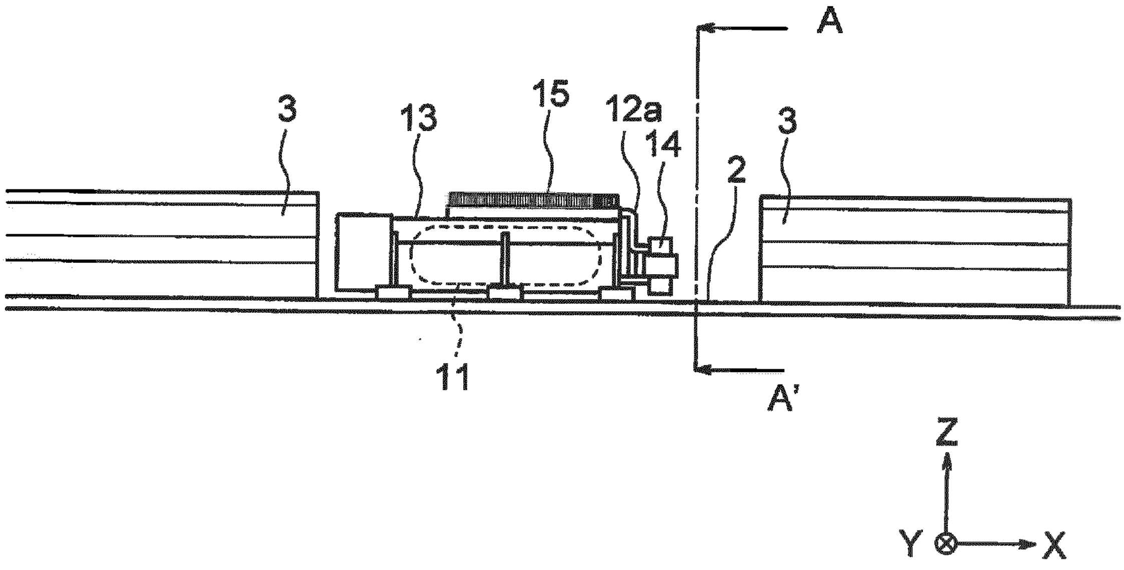


FIG. 6

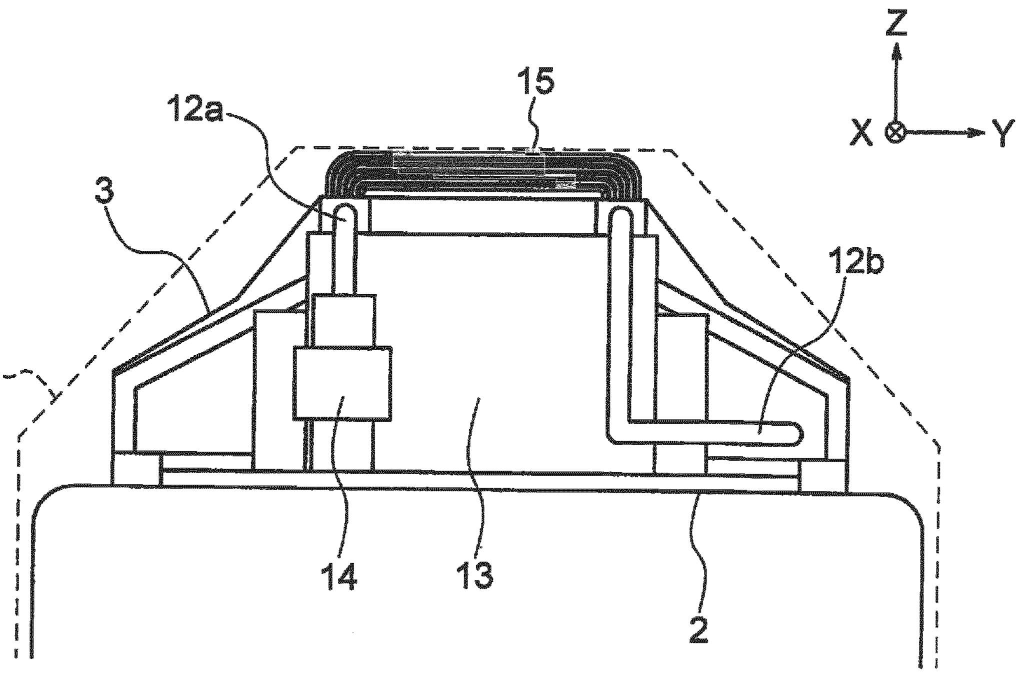

Z
X
Y
15
12a
3
12b
4
14
13
2

FIG. 7

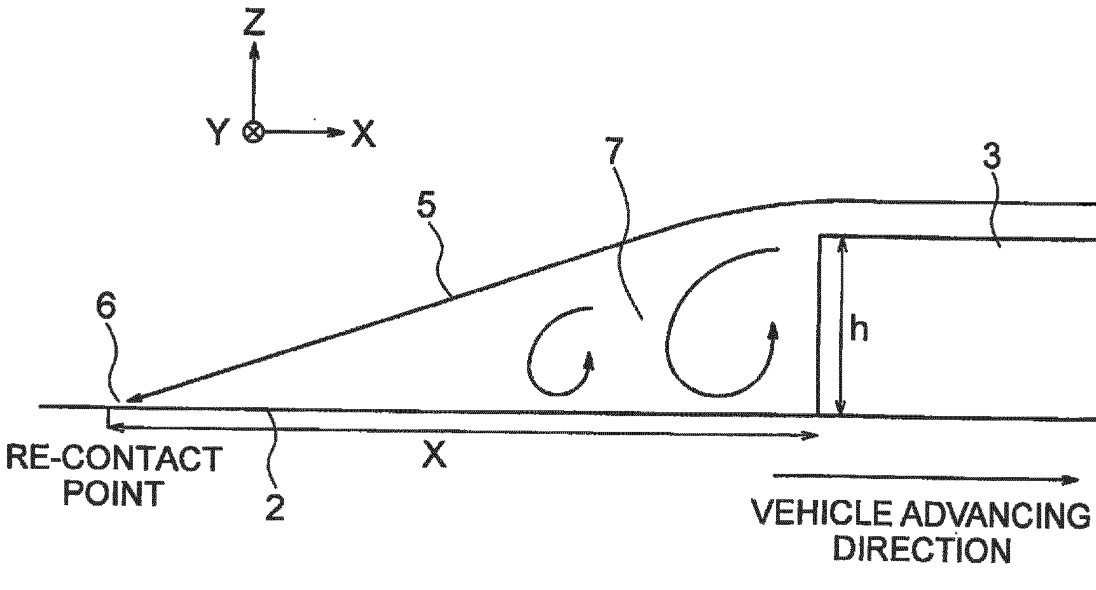

Z
Y
X
7
3
5
6
h
RE-CONTACT POINT
X
2
VEHICLE ADVANCING DIRECTION

FIG. 8

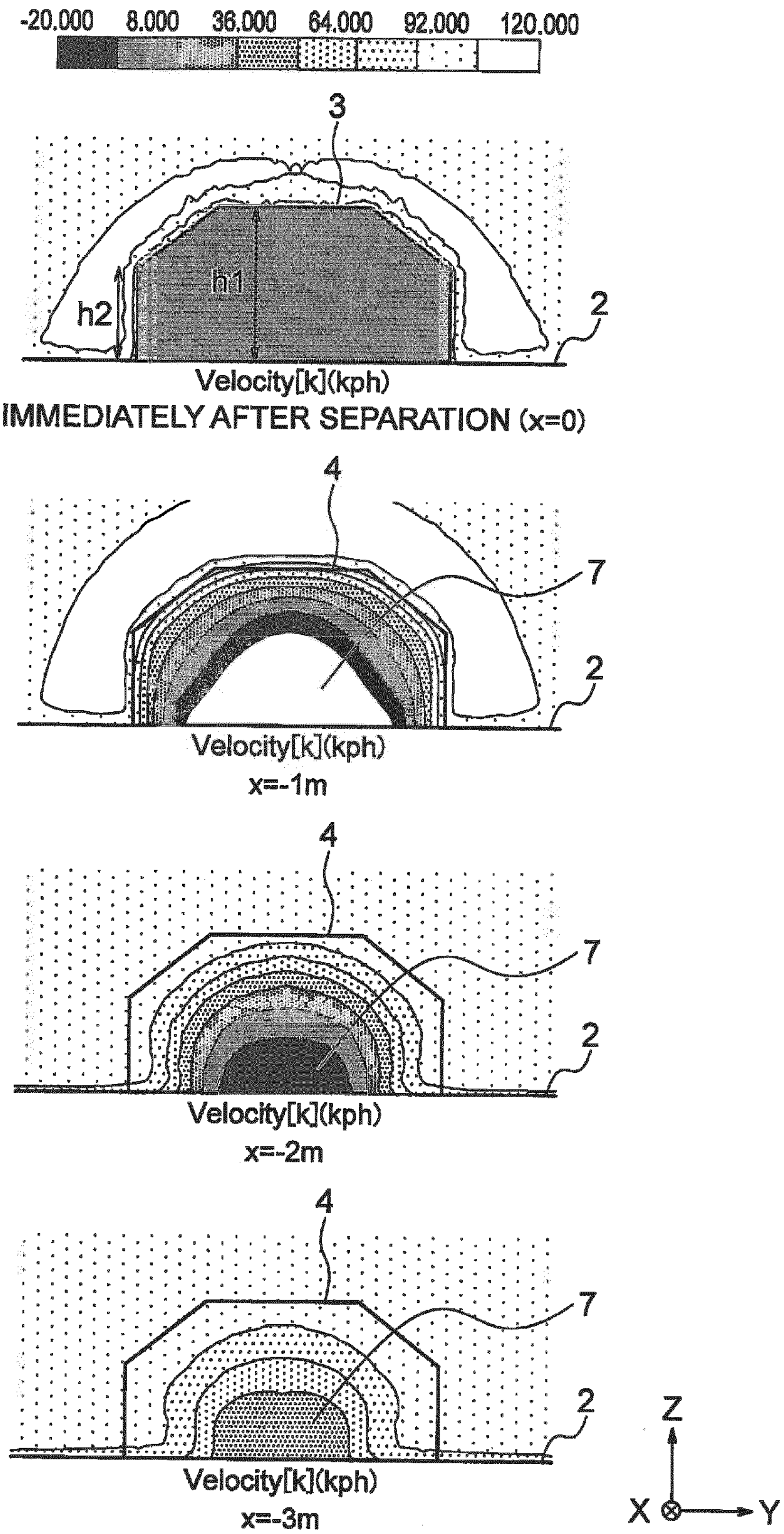

-20.000
8.000
36.000
64.000
92.000
120.000
3
h1
h2
2
Velocity[k](kph)
IMMEDIATELY AFTER SEPARATION (x=0)
4
7
2
Velocity[k](kph)
x=-1m
4
7
2
Velocity[k](kph)
x=-2m
4
7
2
Velocity[k](kph)
x=-3m
Z
X
Y

FIG. 9

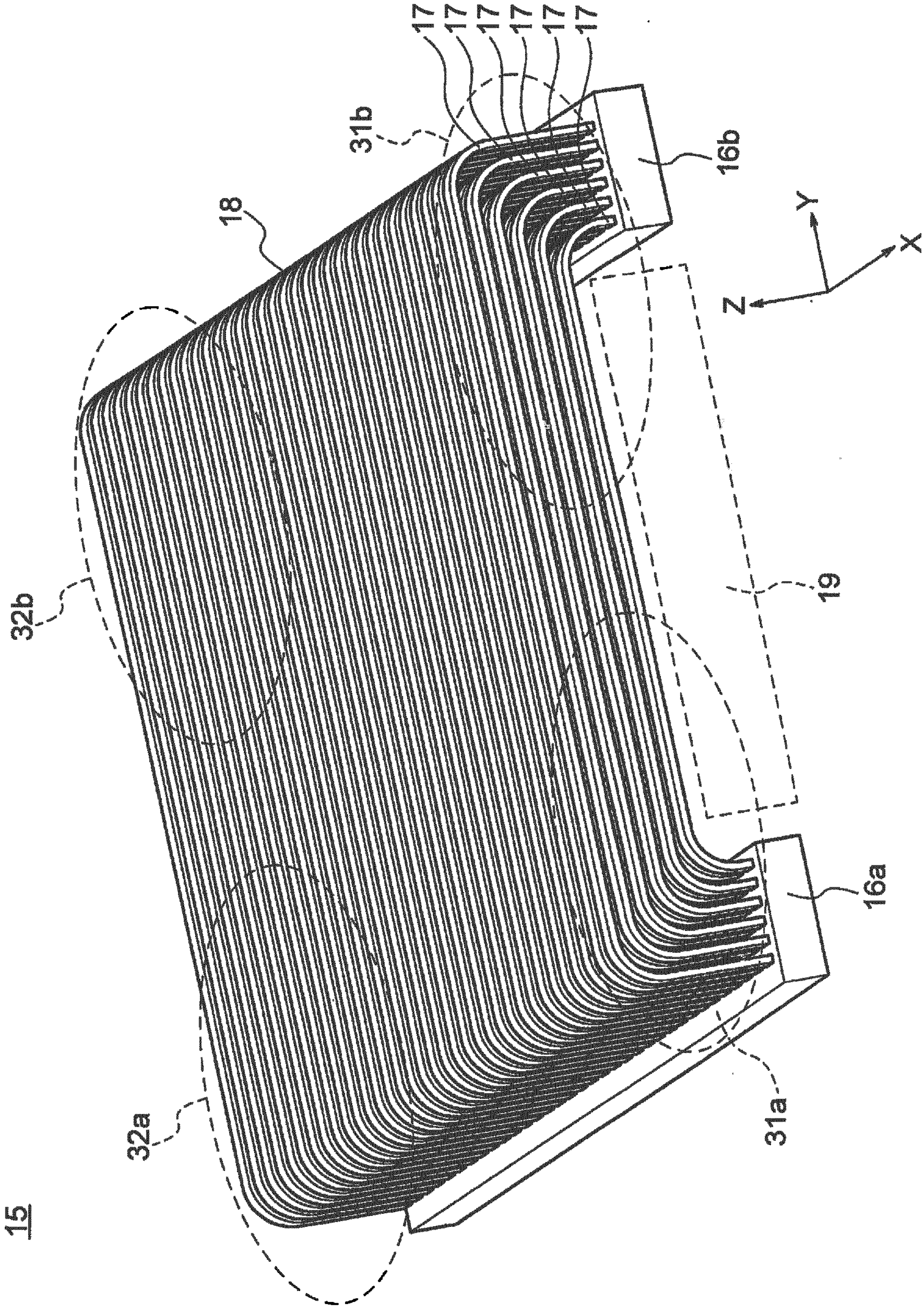


FIG.10

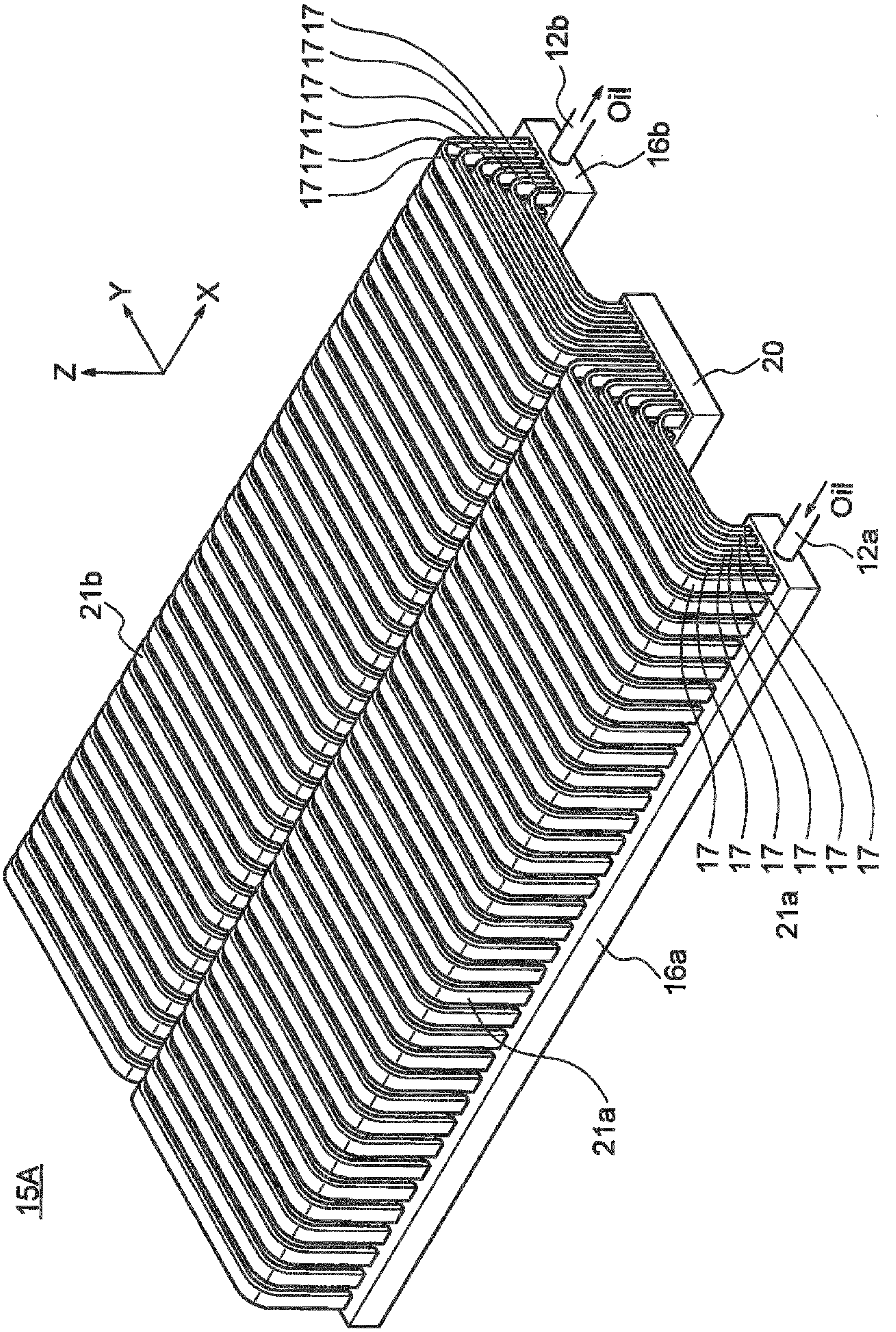


FIG.11

20

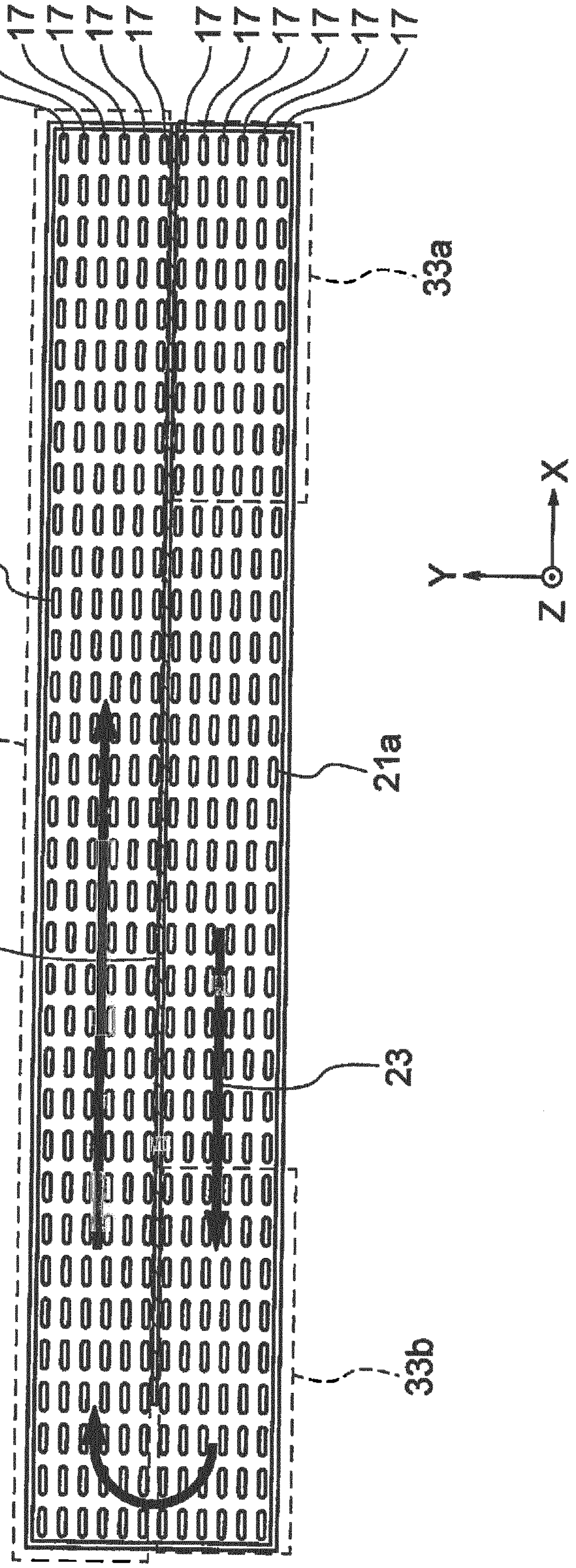


FIG.12

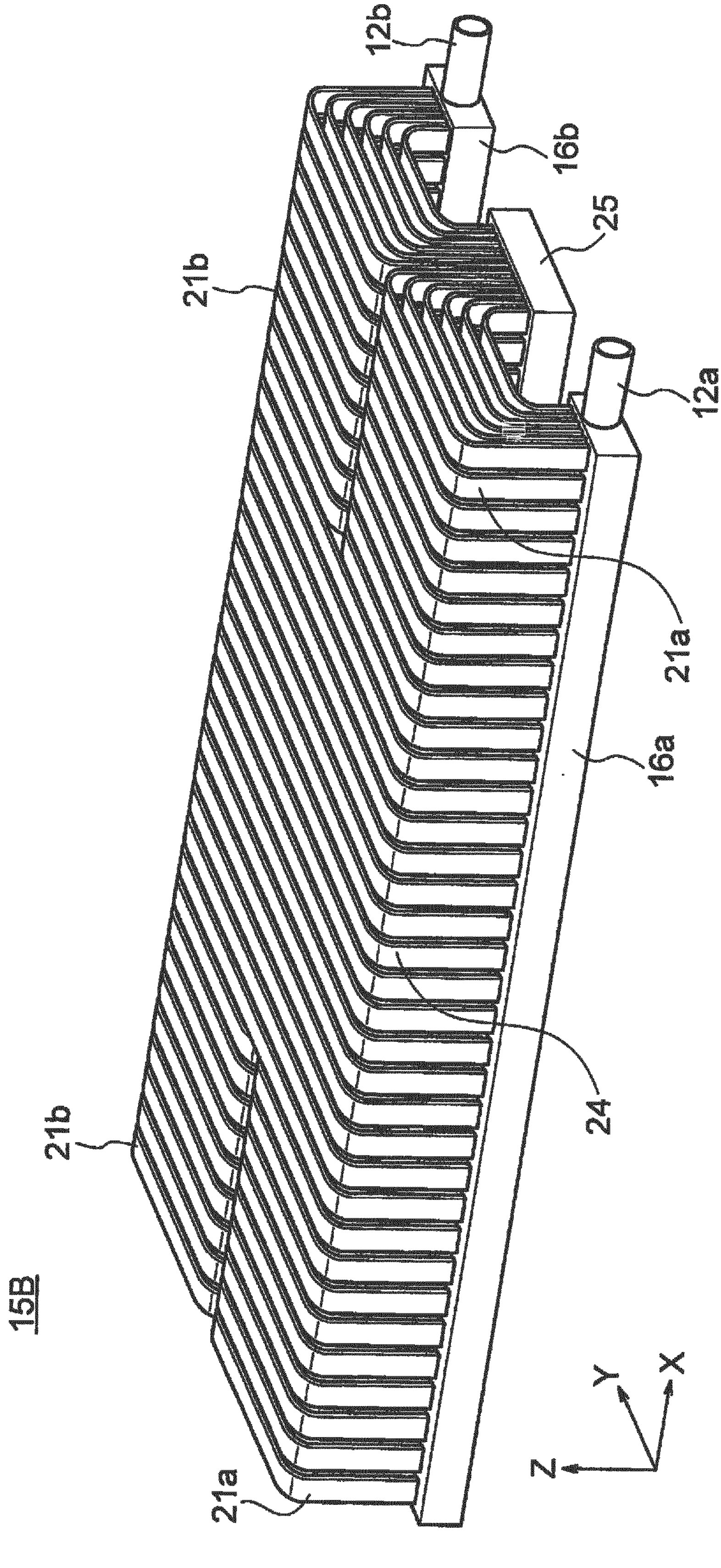


FIG.13

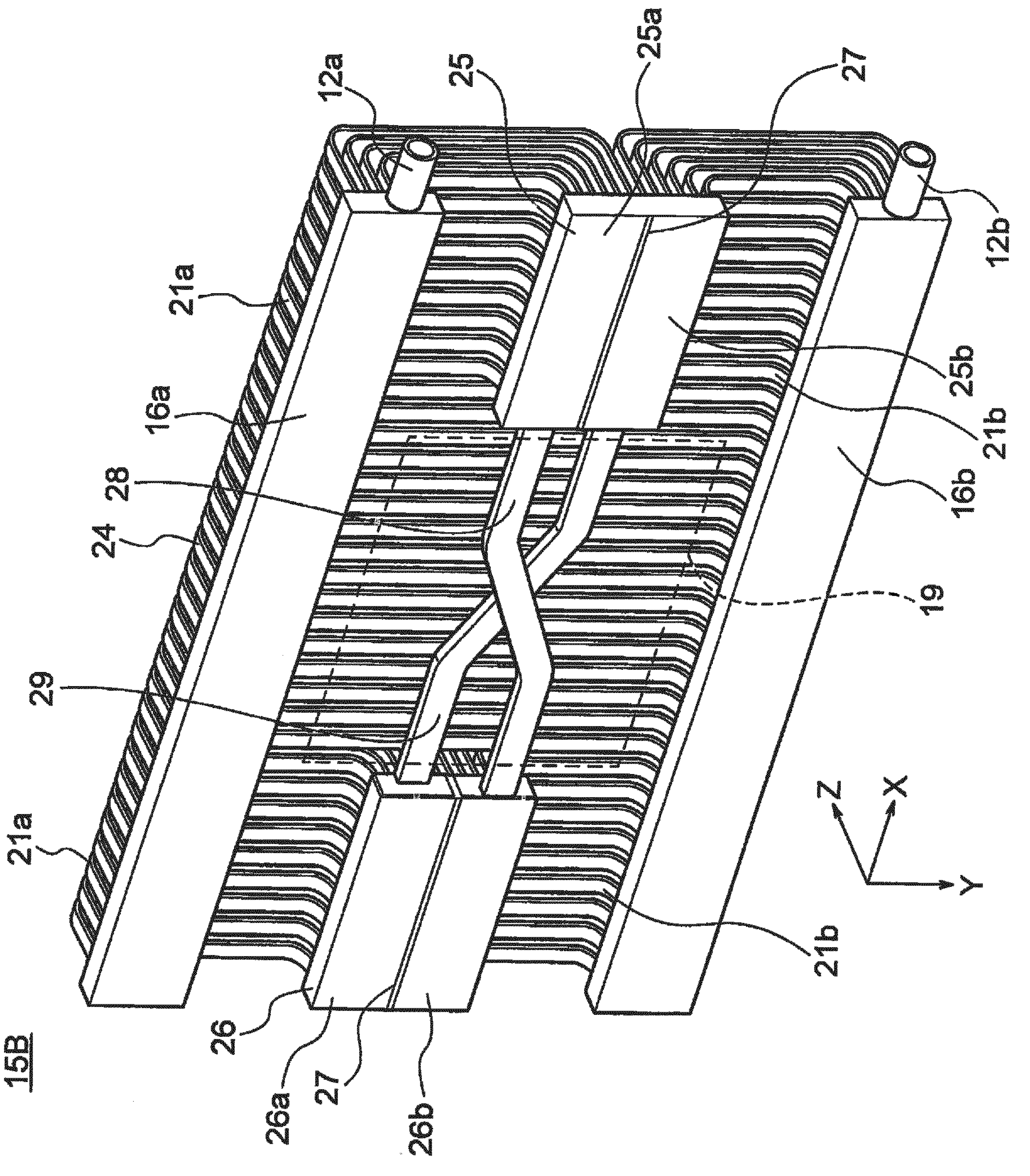
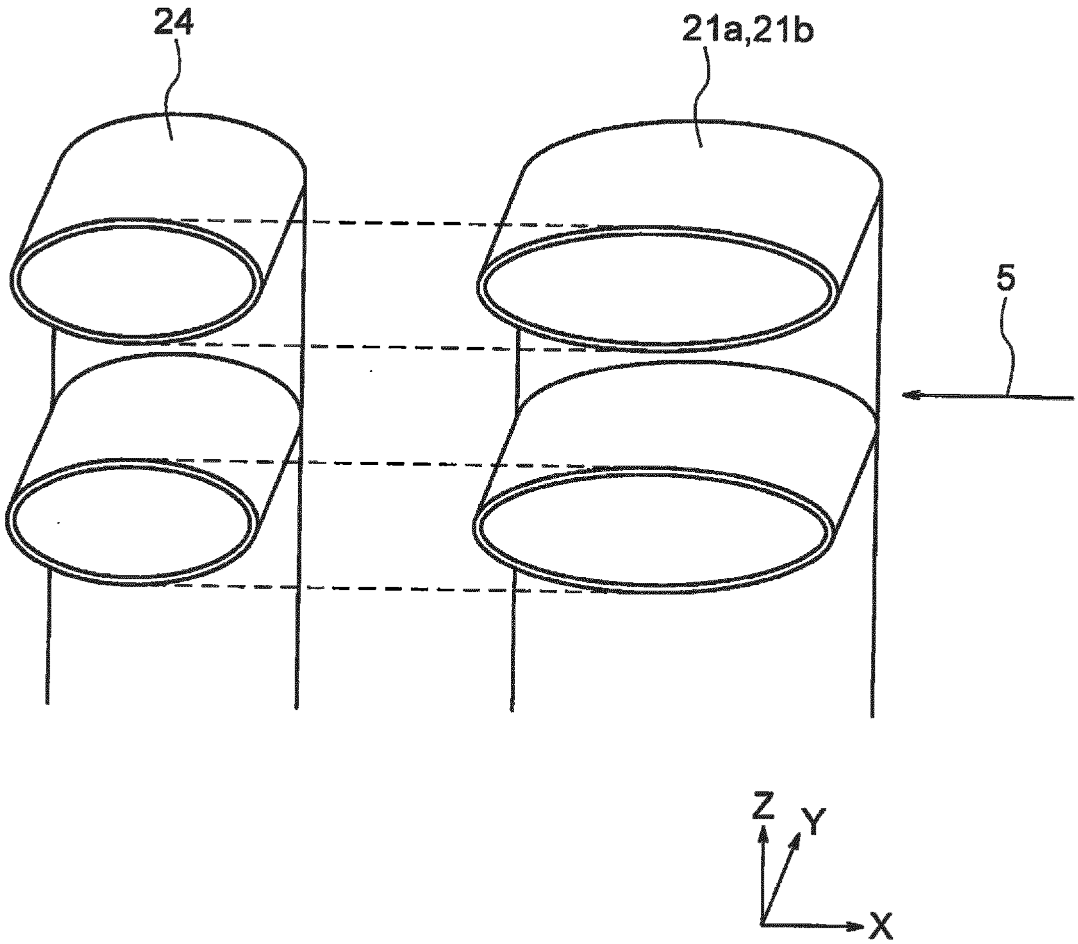

15B
12a
25
25a
27
21a
16a
28
24
29
21a
26
26a
27
26b
21b
12b
25b
21b
16b
19
Z
X
Y

FIG.14



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/076946

A. CLASSIFICATION OF SUBJECT MATTER
H01F27/12(2006.01)i, *B61C17/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01F27/12-27/14, H01F30/06-30/16, H01F38/00, B61C17/00, H05K7/20, F28D1/00-13/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 56-60765 A (Mitsubishi Electric Corp.), 25 May 1981 (25.05.1981), page 1, lower right column, lines 6 to 7; page 2, upper left column, line 13 to lower left column, line 7; page 2, lower right column, line 13 to page 3, upper left column, line 1; fig. 1 to 2, 6 (Family: none)	1-17
Y	JP 2-144904 A (Mitsubishi Electric Corp.), 04 June 1990 (04.06.1990), page 1, lower left column, line 18 to lower right column, line 15; page 2, lower left column, line 5 to lower right column, line 11; fig. 1 to 2, 4 to 5 (Family: none)	1-17

☒ 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
29 November 2016 (29.11.16)	13 December 2016 (13.12.16)

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/076946

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 86222/1977(Laid-open No. 12817/1979) (Mitsubishi Electric Corp.), 27 January 1979 (27.01.1979), specification, page 4, line 9 to page 6, line 5; fig. 3 to 4 (Family: none)	3-17
Y	JP 50-12771 Y1 (Sanyo Electric Co., Ltd.), 19 April 1975 (19.04.1975), column 1, line 33 to column 2, line 27; fig. 1 to 2 (Family: none)	3-7,17
Y	JP 3-158666 A (Showa Aluminum Corp.), 08 July 1991 (08.07.1991), page 2, upper right column, line 3 to lower right column, line 10; fig. 1 to 2 (Family: none)	3-7,17
A	JP 5805354 B1 (Mitsubishi Electric Corp.), 04 November 2015 (04.11.2015), paragraphs [0001], [0013] to [0022]; fig. 1 to 3 & WO 2016/103439 A1	1-17
A	JP 2013-178018 A (Sumitomo Precision Products Co., Ltd.), 09 September 2013 (09.09.2013), paragraphs [0029] to [0053]; fig. 1 to 4 (Family: none)	1-17

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 59084816 U **[0007]**
- JP 2007273777 A **[0007]**