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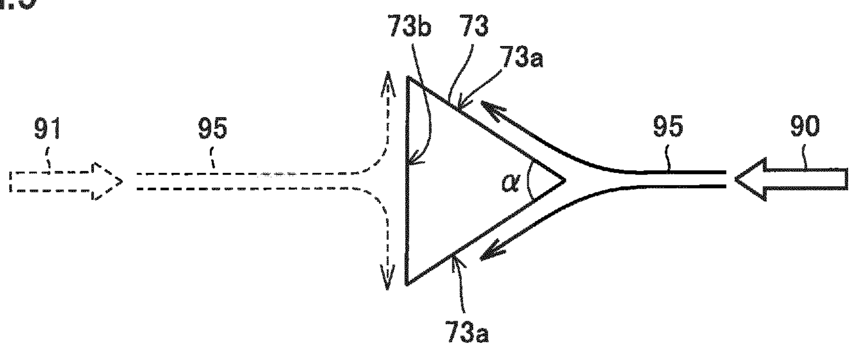
(54) **IN-VEHICLE VOLTAGE-TRANSFORMING DEVICE**

(57) Provided are: a tank configured to contain an iron core, three or more windings, and a plurality of insulating plates and filled with insulation oil; a plurality of spacers each interposed between a winding and an insulating plate facing each other to provide a flow path for the insulation oil; a pump configured to cause the insulation oil to flow; and a switching circuit. A part of the spacers have a smaller flow resistance to the insulation oil flowing in one direction than a flow resistance to the insulation oil flowing in another direction opposite to the one direction. Another part of the spacers have a smaller flow resistance to the insulation oil flowing in the other direction than a flow resistance to the insulation oil flowing in the one direction. The pump is configured to cause the insulation oil to flow in the one direction when the part of the windings is incorporated in an electric circuit by the switching circuit, and the pump is configured to cause the insulation oil to flow in the other direction when the other part of the windings is incorporated in the electric circuit by the switching circuit.

FIG.9



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Description

TECHNICAL FIELD

[0001] The present invention relates to an in-vehicle transformation device, and relates to an in-vehicle oil immersed transformer configured to convert a plurality of types of voltages into a desired voltage.

BACKGROUND ART

[0002] Railroad vehicles such as a Shinkansen Super Express train are required to more quickly transport objects as many as possible. Hence, an in-vehicle transformation device mounted on such a railroad vehicle is required to satisfy contradictory demands, i.e., achieve both large capacitance and downsizing/weight reduction. Further, in recent years, in order to promote barrier-free transportation, a larger number of low-floor vehicles have been introduced. Accordingly, in-vehicle transformation devices are required to have lower heights.

[0003] An AC-DC dual system electric railcar has been developed which is capable of traveling in both (i) an AC zone in which AC voltage is supplied from a wire or the like and (ii) a DC zone in which DC voltage is supplied from a wire or the like. As a prior art document, WO 2010/073337 A1 (Patent Document 1) discloses a configuration of a transformation device usable for such an AC-DC dual system electric railcar.

[0004] The transformation device described in Patent Document 1 includes: an iron core; a plurality of coils wound around the iron core and stacked on one another; a plurality of base members each disposed between adjacent coils in the stacking direction; a plurality of flow path member groups each provided for each coil in a corresponding base member to provide a flow path to allow an insulating liquid to flow between the corresponding base member and the corresponding coil; and a blocking member disposed to (i) block flow of the insulating liquid such that a flow rate of the insulating liquid in at least one of the flow paths each formed by each flow path member group becomes different from a flow rate of the insulating liquid in a flow path other than the at least one of the flow paths, and (ii) block the flow of the insulating liquid in the at least one of the flow paths at a region not overlapping with the iron core in a flow direction of the insulating liquid.

LIST OF CITATIONS

PATENT DOCUMENT

[0005]

PTD 1: WO 2010/073337 A1

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0006] In the transformation device described in Patent Document 1, an increase in temperatures of the windings is made uniform, thus improving cooling efficiency. Hence, the blocking member thus disposed causes increase in temperature of a winding having a low temperature in the first place.

[0007] The present invention has been made in view of the problem, and has an object to provide an in-vehicle transformation device capable of suppressing increase in temperatures of all the windings by selectively cooling a heat-generating winding in response to a change of heat-generating windings.

SOLUTION TO PROBLEM

[0008] An in-vehicle transformation device according to the present invention comprises: an iron core; three or more windings wound around the iron core and stacked on one another; a plurality of insulating plates each disposed between adjacent windings of the three or more windings; a tank configured to contain the iron core, the three or more windings, and the plurality of insulating plates and filled with insulation oil; a plurality of spacers each located and interposed between a winding and an insulating plate facing each other among the three or more windings and the plurality of insulating plates to provide a flow path for the insulation oil; a pump configured to selectively cause the insulation oil to flow in one of one direction and another direction of directions orthogonal to a stacking direction of the three or more windings, the other direction being opposite to the one direction; and a switching circuit configured to selectively incorporate, in an electric circuit, one of a part of the three or more windings and another part of the three or more windings.

[0009] A part of the plurality of spacers in contact with the part of the windings have a smaller flow resistance to the insulation oil flowing in the one direction than a flow resistance to the insulation oil flowing in the other direction. Another part of the plurality of spacers in contact with the other part of the windings have a smaller flow resistance to the insulation oil flowing in the other direction than a flow resistance to the insulation oil flowing in the one direction. The pump is configured to cause the insulation oil to flow in the one direction when the part of the windings is incorporated in the electric circuit by the switching circuit, and the pump is configured to cause the insulation oil to flow in the other direction when the other part of the windings is incorporated in the electric circuit by the switching circuit.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0010] According to the present invention, increase in temperatures of all the windings can be suppressed by selectively cooling a heat-generating winding in response to a change of heat-generating windings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a perspective view showing a configuration of a transformer included in an in-vehicle transformation device according to one embodiment of the present invention.
FIG. 2 is a perspective view of an iron core, a primary winding, and secondary windings shown in FIG. 1.
FIG. 3 is a cross sectional view of the iron core, the primary winding, and the secondary windings when viewed in a direction of III-III line arrows in FIG. 2.
FIG. 4 shows a first state of a configuration of a railroad vehicle according to one embodiment of the present invention.
FIG. 5 shows a second state of the configuration of the railroad vehicle according to one embodiment of the present invention.
FIG. 6 is an exploded perspective view showing a stacking structure of windings, insulating plates, and spacers in the transformer of the in-vehicle transformation device according to one embodiment of the present invention.
FIG. 7 is a cross sectional view showing the stacking structure of the windings, the insulating plates, and the spacers in the transformer of the in-vehicle transformation device according to one embodiment of the present invention.
FIG. 8 is a plan view showing a layout of spacers in contact with the primary winding.
FIG. 9 is a plan view showing a shape of each of a plurality of second spacers of a second spacer unit of the in-vehicle transformation device according to one embodiment of the present invention.
FIG. 10 is a plan view showing a shape of a second spacer of a second spacer unit according to a first modification.
FIG. 11 is a plan view showing a shape of a second spacer of a second spacer unit according to a second modification.
FIG. 12 is a cross sectional view showing a state in which insulation oil flows in one direction within a tank in the in-vehicle transformation device according to one embodiment of the present invention.
FIG. 13 is a cross sectional view showing a state in which the insulation oil flows in the other direction within the tank in the in-vehicle transformation device according to one embodiment of the present invention.
FIG. 14 is a graph showing a temperature of each of the windings when the pump causes the insulation oil to flow in the one direction.
FIG. 15 is a graph showing a temperature of each of the windings when the pump causes the insulation oil to flow in the other direction.

DESCRIPTION OF EMBODIMENTS

[0012] The following describes an in-vehicle transformation device according to one embodiment of the present invention with reference to figures. It should be noted that the same or corresponding portions in the figures are given the same reference characters and are not described repeatedly.
[0013] FIG. 1 is a perspective view showing a configuration of a transformer included in an in-vehicle transformation device according to one embodiment of the present invention. The in-vehicle transformation device according to one embodiment of the present invention is mounted on a railroad vehicle.
[0014] As shown in FIG. 1, a transformer 50 included in the in-vehicle transformation device according to one embodiment of the present invention includes a primary winding (high-voltage side winding) 3, secondary windings (low-voltage side windings) 4a, 4b, terminals 9, an iron core 10, and a tank 21.
[0015] Each of the primary winding 3 and the secondary windings 4a, 4b is wound around the iron core 10. The tank 21 contains the primary winding 3, the secondary windings 4a, 4b, and the iron core 10. The tank 21 is filled with insulation oil (not shown). Each of the secondary windings 4a, 4b has terminals 9.

[0016] The transformer 50 further includes an electric blower 22, a cooler 23, and a conservator 24. The electric blower 22 sends wind to the cooler 23 to cool the insulation oil in the transformer 50 (tank 21). The cooler 23 cools the insulation oil in the transformer 50 (tank 21). It should be noted that wind produced during traveling of the railroad vehicle may be introduced into the cooler 23. In this case, the electric blower 22 can be excluded from the configuration shown in FIG. 1.

[0017] The conservator 24 is expanded or contracted in response to a change in volume of the insulation oil. When the insulation oil is heated by heat generated in the primary winding 3 and the secondary winding 4a, 4b, the volume of the insulation oil is increased. In this case, the conservator 24 is expanded. On the other hand, when the temperature of the insulation oil is decreased, the volume of the insulation oil is decreased. In this case, the conservator 24 is contracted.

[0018] FIG. 2 is a perspective view of the iron core, the primary winding, and the secondary windings shown in FIG. 1. FIG. 3 is a cross sectional view of the iron core, the primary winding, and the secondary windings when viewed in a direction of III-III line arrows in FIG. 2. As shown in FIG. 2 and FIG. 3, the iron core 10 includes a main leg 10a and side legs 10b, 10c. Side legs 10b, 10c are connected to main leg 10a. A window portion W1 is formed in the iron core 10 by main leg 10a and side leg 10b. Similarly, a window portion W2 is formed in the iron core 10 by main leg 10a and side leg 10c.

[0019] The primary winding 3 and the secondary windings 4a, 4b are wound around main leg 10a to pass through window portions W1, W2. In FIG. 3, a Z direction represents a winding axis direction of each of the primary winding 3 and the secondary windings 4a, 4b. The secondary winding 4a is disposed above the primary winding 3, and the secondary winding 4b is disposed below the primary winding 3. In this way, the primary winding 3 and the secondary windings 4a, 4b are stacked on one another.

[0020] Each of the primary winding 3 and the secondary windings 4a, 4b includes plate-like windings 4c each wound in the same plane and composed of a conductor such as aluminum, for example. In the present embodiment, the primary winding 3 is constituted of four plate-like windings 4c, the secondary winding 4a is constituted of two plate-like windings 4c, and the secondary winding 4b is constituted of two plate-like windings 4c. That is, the transformer 50 includes eight plate-like windings 4c.

[0021] FIG. 3 shows a cross section of the iron core 10 in a direction parallel to the winding axis direction of each of the primary winding 3 and the secondary windings 4a, 4b and perpendicular to a direction in which window portions W1, W2 extend. As shown in FIG. 3, the iron core 10 surrounds the primary winding 3 and the secondary windings 4a, 4b. That is, the transformer 50 included in the in-vehicle transformation device according to the present embodiment is a so-called shell type transformer.

[0022] Each of the secondary windings 4a, 4b has two terminals. The secondary winding 4a has terminals 9a, 9b, and the secondary winding 4b has terminals 9c, 9d. The terminals 9a to 9d correspond to terminals 9 shown in FIG. 1. The terminals 9a to 9d are provided outside the iron core 10.

[0023] FIG. 4 shows a first state of a configuration of a railroad vehicle according to the present embodiment. FIG. 5 shows a second state of the configuration of the railroad vehicle according to the present embodiment.

[0024] A railroad vehicle 100 is an AC electric railcar configured to travel in a plurality of zones with different AC voltages. As shown in FIGS. 4 and 5, railroad vehicle 100 includes a pantograph 2, an in-vehicle transformation device 101, and a motor 7. In-vehicle transformation device 101 includes the transformer 50, a converter 5, an inverter 6, and a switching circuit 8. The transformer 50 includes the primary winding 3, the secondary windings 4a, 4b, and the iron core 10.

[0025] The pantograph 2 is connected to a wire 1. The primary winding 3 has

(i) a first terminal connected to pantograph 2 and
(ii) a second terminal provided opposite to this first terminal and connected to a ground node to which ground voltage is supplied.

[0026] Each of the secondary windings 4a, 4b has a first terminal and a second terminal, each of whose potential is not fixed. More specifically, the secondary winding 4a is magnetically coupled to the primary winding 3, and has (i) the terminal 9a provided at one end side of the secondary winding 4a and (ii) the terminal 9b provided at the other end side of the secondary winding 4a. The secondary winding 4b is magnetically coupled to the primary winding 3, and has (i) the terminal 9c provided at one end side of the secondary winding 4b and (ii) the terminal 9d provided at the other end side of the secondary winding 4b. The number of turns of the secondary winding 4a is different from the number of turns of the secondary winding 4b.

[0027] Switching circuit 8 selectively connects one of the secondary winding 4a and the secondary winding 4b to converter 5. That is, switching circuit 8 selectively connects the first and second terminals of each of the secondary windings 4a, 4b to converter 5.

[0028] More specifically, the switching circuit 8 switches between (i) the first state in which the terminal 9a and the terminal 9b of the secondary winding 4a are respectively connected to the first and second input terminals of converter 5 as shown in FIG. 4 and (ii) the second state in which the terminal 9c and the terminal 9d of the secondary winding 4b are respectively connected to the first and second input terminals of converter 5 as shown in FIG. 5.

[0029] Thus, the switching circuit 8 selectively incorporates, in an electric circuit, one of the secondary winding 4a, which is a part of eight plate-like windings 4c, and the secondary winding 4b, which is another part of the eight plate-like windings 4c. The secondary winding 4a is a part of the secondary windings, and the secondary winding 4b is the rest of the secondary windings other than the part of the secondary windings.

[0030] A single-phase AC voltage, which is supplied from the wire 1, is supplied to the primary winding 3 via the pantograph 2. The AC voltage thus supplied to the primary winding 3 induces AC voltages in the secondary windings 4a and 4b.

[0031] Converter 5 converts, into DC voltage, the AC voltage induced in the secondary winding 4a or the secondary winding 4b connected to converter 5 by switching circuit 8. Inverter 6 converts, into three-phase AC voltage, the DC voltage received from converter 5, and outputs it to motor 7. Motor 7 is driven using the three-phase AC voltage received from inverter 6.

[0032] In railroad vehicle 100 having the above configuration, a secondary winding to be used is selected by switching circuit 8 in accordance with a magnitude of AC voltage supplied from wire 1.

[0033] The following describes a plurality of insulating plates and a plurality of spacers included in the transformer 50 of in-vehicle transformation device 101 according to the present embodiment.

[0034] FIG. 6 is an exploded perspective view showing a stacking structure of the windings, the insulating plates, and the spacers in the transformer of the in-vehicle transformation device according to the present embodiment. FIG. 7 is a cross sectional view showing the stacking structure of the windings, the insulating plates, and the spacers in the transformer of the in-vehicle transformation device according to the present embodiment. FIG. 8 is a plan view showing a layout of spacers in contact with the primary winding.

[0035] It should be noted that FIG. 6 representatively shows insulating plates adjacent to the primary winding 3 and a plurality of spacers attached to the insulating plates, as well as insulating plates adjacent to the secondary winding 4b and a plurality of spacers attached to the insulating plates. Moreover, for ease of illustration in FIG. 6, the positions and shapes of the plurality of spacers attached to each of all the insulating plates are illustrated to be the same as those of the spacers in contact with the primary winding 3.

[0036] As shown in FIGS. 6 to 8, in-vehicle transformation device 101 further includes seven insulating plates 61 each disposed between adjacent ones of eight plate-like windings 4c. Seven insulating plates 61 are contained in the tank 21.

[0037] Further, in the present embodiment, one insulating plate 61 is disposed on the secondary winding 4a located at the uppermost layer, and one insulating plate 61 is disposed below the secondary winding 4b located at the lowermost layer. However, no spacers are attached to these two insulating plates 61.

[0038] Each insulating plate 61 is composed of an insulating material, examples of which include: insulating paper such as a pressboard; or an insulating material such as polyamide. When viewed in a plan view, each insulating plate 61 has a substantially rectangular outer shape, and an opening to which the iron core 10 is to be inserted is provided at the center of the insulating plate 61. The four corners of each insulating plate 61 are cut off.

[0039] In-vehicle transformation device 101 further includes a plurality of spacers each located and interposed between a plate-like winding 4c and an insulating plate 61 facing each other among eight plate-like windings 4c and seven insulating plates 61 to provide a flow path for the insulation oil.

[0040] There are the following three combinations of plate-like winding 4c and the insulating plate 61 facing each other: the primary winding 3 and the insulating plate 61; the secondary winding 4a and the insulating plate 61; and the secondary winding 4b and the insulating plate 61.

[0041] In the present embodiment, each of the plurality of spacers is attached by an adhesive agent onto at least one main surface of each insulating plate 61. However, the present embodiment should not be limited to this, and each of the plurality of spacers may be attached by an adhesive agent onto at least one main surface of each plate-like winding 4c. Each of the plurality of spacers is composed of an insulating material, examples of which include: insulating paper such as a pressboard; or an insulating resin such as polypropylene.

[0042] Specifically, a plurality of first spacers 62 and a plurality of second spacers 63 are disposed between the primary winding 3 and the insulating plate 61. Each of the plurality of first spacers 62 and the plurality of second spacers 63 is interposed between the primary winding 3 and the insulating plate 61 facing each other to provide a flow path for the insulation oil.

[0043] A first spacer unit 60 is constituted of the insulating plate 61 and the plurality of first spacers 62 and the plurality of second spacers 63 attached to the insulating plate 61. The first spacer unit 60 is disposed such that a direction in which one end 60a of the first spacer unit 60 is connected to the other end 60b of the first spacer unit 60 in the shortest distance is in parallel with a flow direction of the insulation oil.

[0044] The plurality of second spacers 63 are separately located at both the one end 60a side and the other end 60b side of the first spacer unit 60, and the plurality of first spacers 62 are located at the central side of the first spacer unit 60 at a region not overlapping with the iron core 10.

[0045] Each of two of three insulating plates 61 facing the primary winding 3 has one main surface to which the plurality of first spacers 62 and the plurality of second spacers 63 are attached, and has the other main surface in contact with the adjacent primary winding 3. One remaining insulating plate 61 has main surfaces to both of which the plurality of first spacers 62 and the plurality of second spacers 63 are attached.

[0046] Between the secondary winding 4a and the insulating plate 61, a plurality of first spacers 72 and a plurality of second spacers 73 are disposed. Each of the plurality of first spacers 72 and the plurality of second spacers 73 is interposed between the primary winding 3 and the insulating plate 61 facing each other to provide a flow path for the insulation oil.

[0047] A second spacer unit 70 is constituted of the insulating plate 61 and the plurality of first spacers 72 and the plurality of second spacers 73 attached to the insulating plate 61. The second spacer unit 70 is disposed such that a direction in which one end 70a of the second spacer unit 70 is connected to the other end 70b of the second spacer unit 70 in the shortest distance is in parallel with a flow direction of the insulation oil.

[0048] The plurality of second spacers 73 are separately located at both the one end 70a side and the other end 70b side of the second spacer unit 70, and the plurality of first spacers 72 are located at the central side of the second spacer unit 70 at a region not overlapping with the iron core 10.

[0049] Each of two insulating plates 61 facing the secondary winding 4a has one main surface to which the plurality of first spacers 72 and the plurality of second spacers 73 are attached, and has the other main surface in contact with the adjacent primary winding 3 or the secondary winding 4a.

[0050] Between the secondary winding 4b and the insulating plate 61, the plurality of first spacers 72 and the plurality of second spacers 73 are disposed. Each of the plurality of first spacers 72 and the plurality of second spacers 73 is interposed between the primary winding 3 and the insulating plate 61 facing each other to provide a flow path for the insulation oil.

[0051] The plurality of second spacers 73 are separately located at both the one end 70a side and the other end 70b side of the second spacer unit 70, and the plurality of first spacers 72 are located at the central side of the second spacer unit 70 at a region not overlapping with the iron core 10.

[0052] Each of two insulating plates 61 facing the secondary winding 4b has one main surface to which the plurality of first spacers 72 and the plurality of second spacers 73 are attached, and has the other main surface in contact with the adjacent primary winding 3 or the secondary winding 4b.

[0053] As described above, in the present embodiment, the second spacer unit 70 for providing the flow path for the insulation oil between the second spacer unit 70 and the secondary winding 4a has the same shape as the second spacer unit 70 for providing the flow path for the insulation oil between the second spacer unit 70 and the secondary winding 4b, and these second spacer units 70 are disposed in opposite orientations when viewed in a plan view.

[0054] Specifically, these second spacer units 70 are disposed in opposite orientations such that the locations of one end 70a and the other end 70b of one second spacer unit 70 are reverse to the locations of one end 70a and the other end 70b of the other second spacer unit 70.

[0055] Hence, each second spacer 73 in contact with the secondary winding 4a and each second spacer 73 in contact with the secondary winding 4b are constituted of the spacers having the same shape and disposed in the opposite orientations when viewed in a plan view.

[0056] Each of the plurality of first spacers 62 and the plurality of first spacers 72 has the same rectangular outer shape when viewed in a plan view, and are disposed at substantially the same locations on respective insulating plates 61. Each of the plurality of first spacers 62 and the plurality of first spacers 72 has two long sides along a flow direction of the insulation oil, and has two short sides substantially normal to the flow direction of the insulation oil.

[0057] When viewed in a plan view, each of the plurality of second spacers 63 has a rectangular shape, has two long sides normal to the flow direction of the insulation oil, and has two short sides along the flow direction of the insulation oil. Accordingly, in each of the plurality of first spacers 62 of the first spacer unit 60, flow resistance to the insulation oil flowing in one direction is the same as flow resistance to the insulation oil flowing in the other direction as described later.

[0058] FIG. 9 is a plan view showing the shape of each of the plurality of second spacers of the second spacer unit of the in-vehicle transformation device according to the present embodiment. As shown in FIG. 9, when viewed in a plan view, each of the plurality of second spacers 73 of the second spacer unit 70 has (i) two sides 73a forming an acute interior angle α, and (ii) a side 73b opposite to two sides 73a and substantially normal to flow directions 90 and 91 of the insulation oil 95.

[0059] In the present embodiment, the shape of each of the plurality of second spacers 73 of the second spacer unit 70 is a triangular shape when viewed in a plan view but should not be limited to the triangular shape, and may be a trapezoidal shape or the like having the above-described sides. When the shape of the second spacer 73 in contact with the secondary winding 4a is configured to be different from the shape of the second spacer 73 in contact with the secondary winding 4b, one of the second spacers 73 may have the above-described shape.

[0060] Two sides 73a of the second spacer 73 are exposed to the insulation oil 95 flowing in one direction 90 of the flow directions, and side 73b of the second spacer 73 is exposed to the insulation oil 95 flowing in the other direction 91 of the flow directions, so that flow resistance to the insulation oil 95 flowing in one direction 90 of the flow directions is smaller than flow resistance to the insulation oil 95 flowing in the other direction 91 of the flow directions.

[0061] As described above, the second spacer 73 in contact with the secondary winding 4a and the second spacer 73 in contact with the secondary winding 4b are disposed in opposite orientations when viewed in a plan view. Hence, when the second spacer 73 in contact with the secondary winding 4a is disposed as shown in FIG. 9, the second spacer 73 in contact with the secondary winding 4a has a smaller flow resistance to the insulation oil 95 flowing in one direction 90 than the flow resistance to the insulation oil 95 flowing in the other direction 91, and the second spacer 73 in contact with the secondary winding 4b has a smaller flow resistance to the insulation oil 95 flowing in the other direction 91 than the flow resistance to the insulation oil 95 flowing in one direction 90.

[0062] Here, the following describes a modification of the shape of the second spacer 73 of the second spacer unit 70. FIG. 10 is a plan view showing a shape of a second spacer of a second spacer unit according to a first modification. FIG. 11 is a plan view showing a shape of a second spacer of a second spacer unit according to a second modification.

[0063] As shown in FIG. 10, a second spacer 73x of the second spacer unit according to the first modification has (i) two sides 73xa forming an acute interior angle α, and (ii) other two sides 73xb opposite to the two sides 73xa and forming an obtuse interior angle β_1 when viewed in a plan view. The interior angle β_1 is larger than 180°.

[0064] Two sides 73xa of the second spacer 73x are exposed to the insulation oil 95 flowing in one direction 90 of the flow directions, and side 73xb of the second spacer 73x is exposed to the insulation oil 95 flowing in the other direction 91 of the flow directions, so that the flow resistance to the insulation oil 95 flowing in one direction 90 of the flow directions is smaller than the flow resistance to the insulation oil 95 flowing in the other direction 91 of the flow directions.

[0065] As shown in FIG. 11, a second spacer 73y of the second spacer unit according to the second modification has (i) two sides 73ya forming an acute interior angle α, and (ii) other two sides 73yb opposite to the two sides 73ya and forming an obtuse interior angle β_2 when viewed in a plan view. The interior angle β_2 is more than 90° and not more than 180°.

[0066] Two sides 73ya of the second spacer 73y are exposed to the insulation oil 95 flowing in one direction 90 of the flow directions, and the side 73yb of the second spacer 73y is exposed to the insulation oil 95 flowing in the other direction 91 of the flow directions, so that the flow resistance to the insulation oil 95 flowing in one direction 90 of the flow directions is smaller than the flow resistance to the insulation oil 95 flowing in the other direction 91 of the flow directions.

[0067] As described above, the shape of the second spacer of the second spacer unit is not particularly limited as long as the second spacer has such a shape that the flow resistance to the insulation oil 95 flowing in one direction 90 is smaller than the flow resistance to the insulation oil 95 flowing in the other direction 91.

[0068] FIG. 12 is a cross sectional view showing a state in which the insulation oil flows in the one direction within the tank in the in-vehicle transformation device according to the present embodiment. FIG. 13 is a cross sectional view showing a state in which the insulation oil flows in the other direction within the tank in the in-vehicle transformation device according to the present embodiment.

[0069] As shown in FIGS. 12 and 13, the in-vehicle transformation device according to the present embodiment further includes a pump 25 configured to selectively cause the insulation oil to flow in one of (i) one direction 90 of directions orthogonal to the stacking direction of eight plate-like windings 4c and (ii) the other direction 91 opposite to this one direction 90. The tank 21 has two openings 21h.

[0070] In order to cause the insulation oil to flow in one direction 90, the pump 25 circulates the insulation oil such that the insulation oil flows from one opening 21h to the other opening 21h through window portions W1, W2. In order to cause the insulation oil to flow in the other direction 91, the pump 25 circulates the insulation oil such that the insulation oil flows from the other opening 21h to one opening 21h through window portions W1, W2.

[0071] The pump 25 causes the insulation oil to flow in one direction 90 when the secondary winding 4a is incorporated in the electric circuit by switching circuit 8, whereas the pump 25 causes the insulation oil to flow in the other direction 91 when the secondary winding 4b is incorporated in the electric circuit by switching circuit 8.

[0072] As described above, the second spacer 73 in contact with the secondary winding 4a has a smaller flow resistance to insulation oil 95 flowing in one direction 90 than the flow resistance to insulation oil 95 flowing in the other direction 91, and the second spacer 73 in contact with the secondary winding 4b has a smaller flow resistance to insulation oil 95 flowing in the other direction 91 than the flow resistance to insulation oil 95 flowing in one direction 90.

[0073] Therefore, by the pump 25 causing the insulation oil to flow in one direction 90, the insulation oil mainly flows in the vicinity of the primary winding 3 and the secondary winding 4a, and hardly flows around the secondary winding 4b as shown in FIG. 12.

[0074] As a result, the primary winding 3 and the secondary winding 4a, which are incorporated in the electric circuit and generates heat, can be cooled intensively, whereas the secondary winding 4b, which is not incorporated in the electric circuit and hardly generates heat, can be suppressed from being cooled unnecessarily.

[0075] On the other hand, by the pump 25 causing the insulation oil to flow in the other direction 91, the insulation oil mainly flows in the vicinity of the primary winding 3 and the secondary winding 4b, and hardly flows around the secondary winding 4a as shown in FIG. 13.

[0076] As a result, the primary winding 3 and the secondary winding 4b, which are incorporated in the electric circuit and generates heat, can be cooled intensively, whereas the secondary winding 4a, which is not incorporated in the electric circuit and hardly generates heat, can be suppressed from being cooled unnecessarily.

[0077] FIG. 14 is a graph showing a temperature of each of the windings when the pump causes the insulation oil to flow in the one direction. FIG. 15 is a graph showing a temperature of each of the windings when the pump causes the insulation oil to flow in the other direction. In each of FIGS. 14 and 15, the vertical axis represents the windings, and the horizontal axis represents the temperatures of the windings.

[0078] As shown in FIGS. 14 and 15, in the in-vehicle transformation device according to the present embodiment, the windings incorporated in the electric circuit and generating heat are cooled intensively, whereby the temperatures of the windings can be made equal to or less than a reference value TG. Moreover, the temperature of the winding not incorporated in the electric circuit and hardly generating heat is not increased. In other words, the in-vehicle transformation device 101 according to the present embodiment can suppress increase in temperatures of all the windings by selectively cooling a heat-generating winding in response to a change of heat-generating windings.

[0079] It should be noted that the above-described embodiments disclosed herein are illustrative in any respect and do not serve as grounds for restrictive interpretation. Therefore, the technical scope of the present invention is not interpreted only in view of the above-described embodiments, and is defined by the description of claims. Moreover, all the modifications equivalent to the claims in terms of meaning and scope are encompassed.

REFERENCE SIGNS LIST

[0080]

1	wire
2	pantograph
3	primary winding
4a, 4b	secondary winding
4c	plate-like winding
5	converter
6	inverter
7	motor
8	switching circuit
9, 9a, 9b, 9c, 9d	terminal
10	iron core
10a	main leg
10b, 10c	side leg
21	tank
21h	opening
22	electric blower
23	cooler
24	conservator
25	pump
50	transformer
60	first spacer unit
60a, 70a	one end
60b, 70b	other end
61	insulating plate
62, 72	first spacer
63, 73, 73x, 73y	second spacer
70	second spacer unit
90	one direction
91	other direction
95	insulation oil
100	railroad vehicle
101	in-vehicle transformation device
TG	reference value
W1, W2	window portion

Claims

1. An in-vehicle transformation device comprising:

   - an iron core;
   - three or more windings wound around the iron core and stacked on one another;
   - a plurality of insulating plates each disposed between adjacent windings of the three or more windings;
   - a tank configured to contain the iron core, the three or more windings, and the plurality of insulating plates and filled with insulation oil;
   - a plurality of spacers each located and interposed between a winding and an insulating plate facing each other among the three or more windings and the plurality of insulating plates to provide a flow path for the insulation oil;
   - a pump configured to selectively cause the insulation oil to flow in one of one direction and another direction of directions orthogonal to a stacking direction of the three or more windings, the other direction being opposite to the one direction; and
   - a switching circuit configured to selectively incorporate, in an electric circuit, one of a part of the three or more windings and another part of the three or more windings,
   - a part of the plurality of spacers in contact with the part of the windings having a smaller flow resistance to the insulation oil flowing in the one direction than a flow resistance to the insulation oil flowing in the other direction,
   - another part of the plurality of spacers in contact with the other part of the windings having a smaller flow resistance to the insulation oil flowing in the other direction than a flow resistance to the insulation oil flowing in the one direction,
   - the pump being configured to cause the insulation oil to flow in the one direction when the part of the windings is incorporated in the electric circuit by the switching circuit, the pump being configured to cause the insulation oil to flow in the other direction when the other part of the windings is incorporated in the electric circuit by the switching circuit.

2. The in-vehicle transformation device according to claim 1, wherein
the three or more windings includes a primary winding and secondary windings,
the part of the windings is a part of the secondary windings, and
the other part of the windings is a rest of the secondary windings other than the part of the secondary windings.

3. The in-vehicle transformation device according to claim 1,
wherein the part of the spacers and the other part of the spacers are constituted of spacers having the same shape and disposed in opposite orientations when viewed in a plan view.

4. The in-vehicle transformation device according to claim 1 or 2,
wherein at least one of each of the part of the spacers and each of the other part of
the spacers has (i) two sides forming an acute interior angle and (ii) a side opposite to the two sides and substantially normal to a flow direction of the insulation oil when viewed in a plan view.

5. The in-vehicle transformation device according to claim 1 or 2,
wherein at least one of each of the part of the spacers and each of the other part of
the spacers has (i) two sides forming an acute interior angle and (ii) other two sides opposite to the two sides and forming an obtuse interior angle when viewed in a plan view.

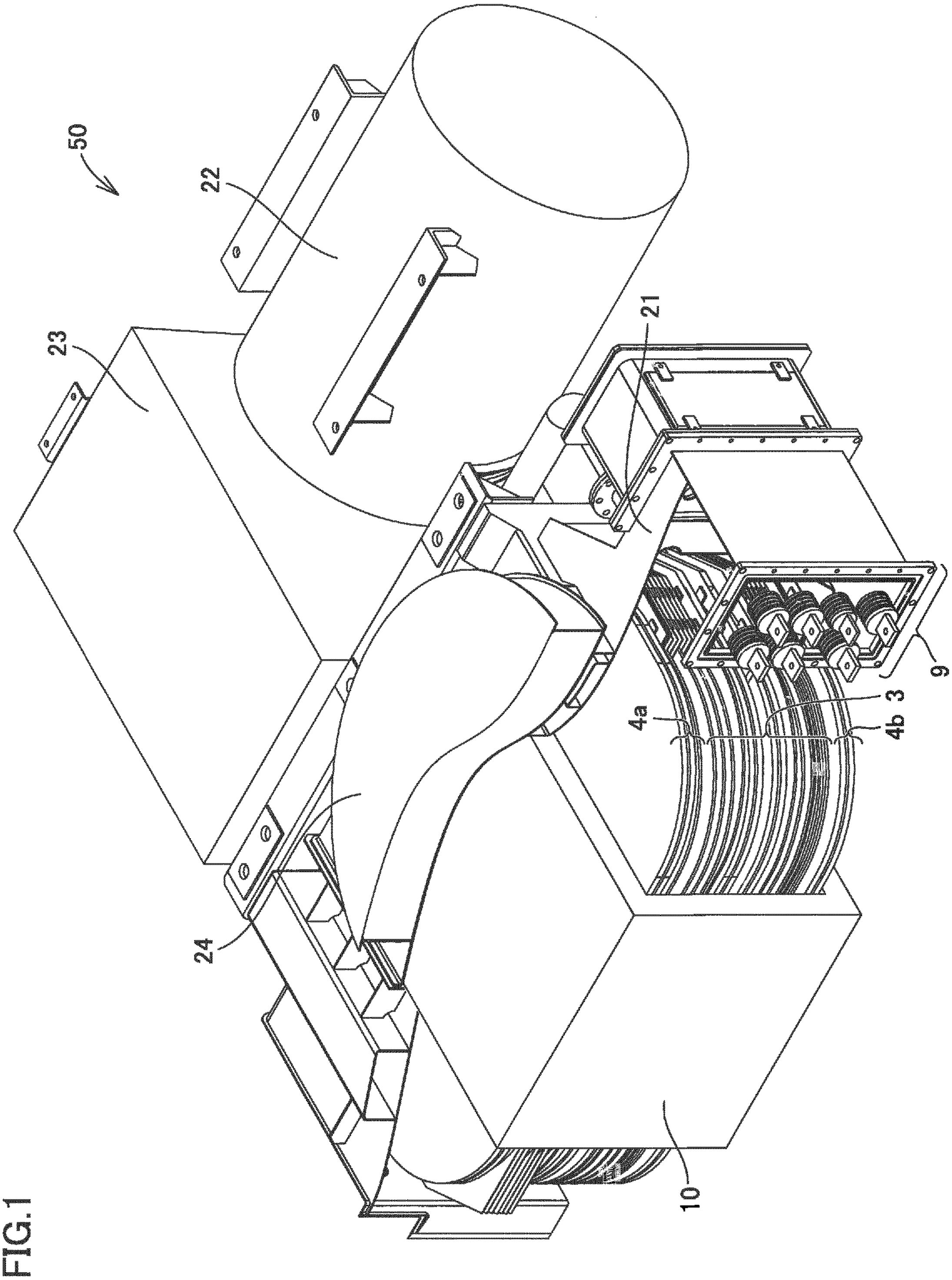


FIG.1

FIG.2

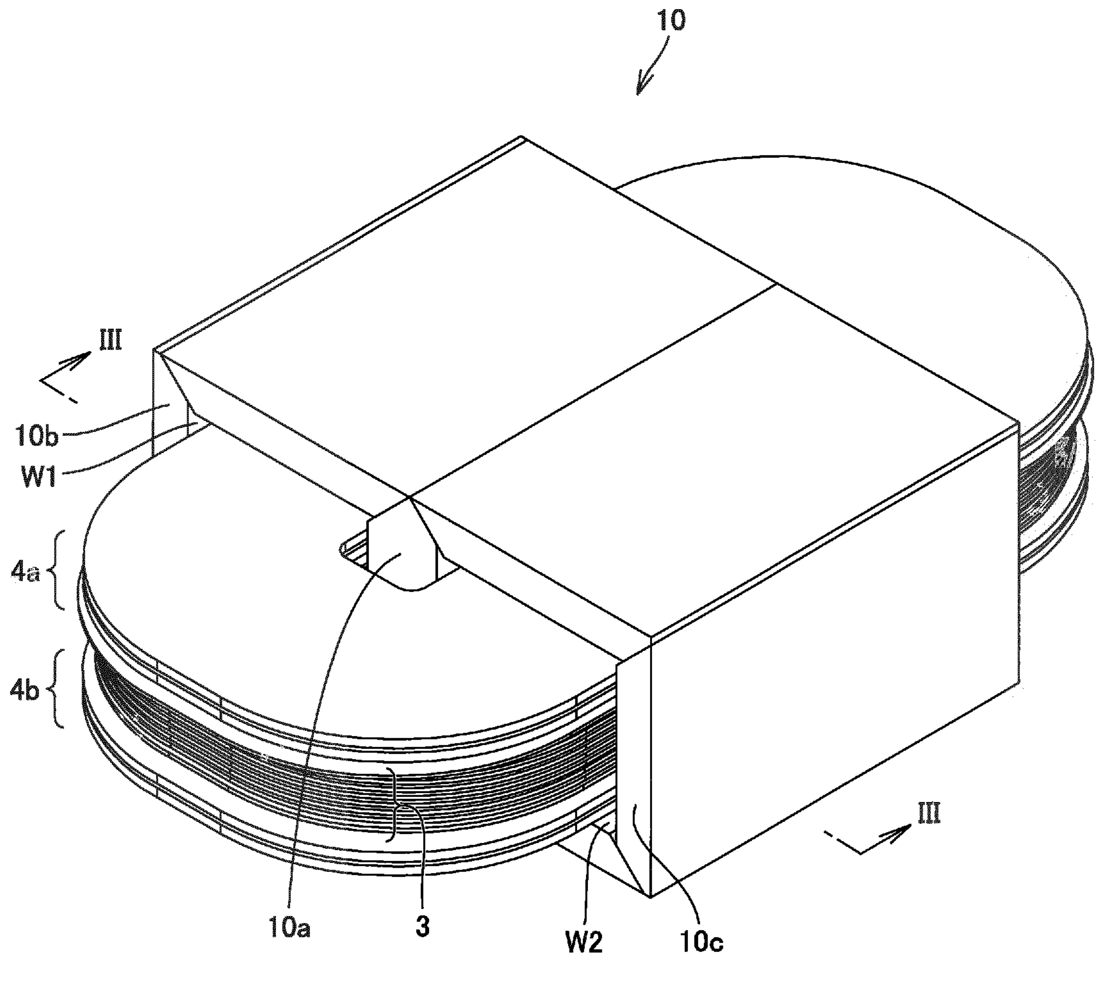


FIG.3

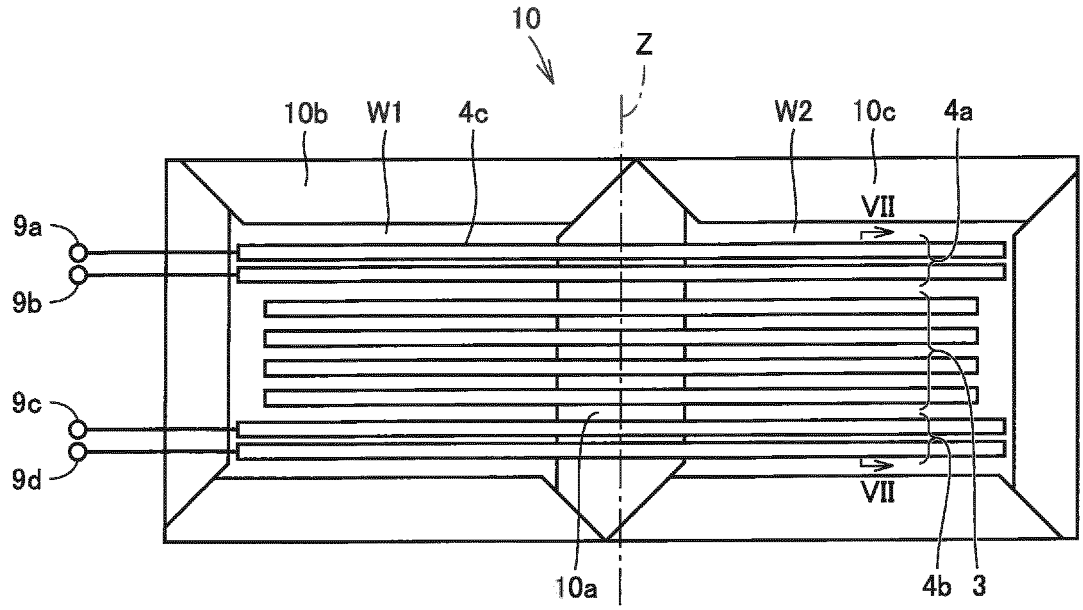

10
Z
10b
W1
4c
W2
10c
4a
VII
9a
9b
9c
9d
VII
10a
4b
3

FIG.4

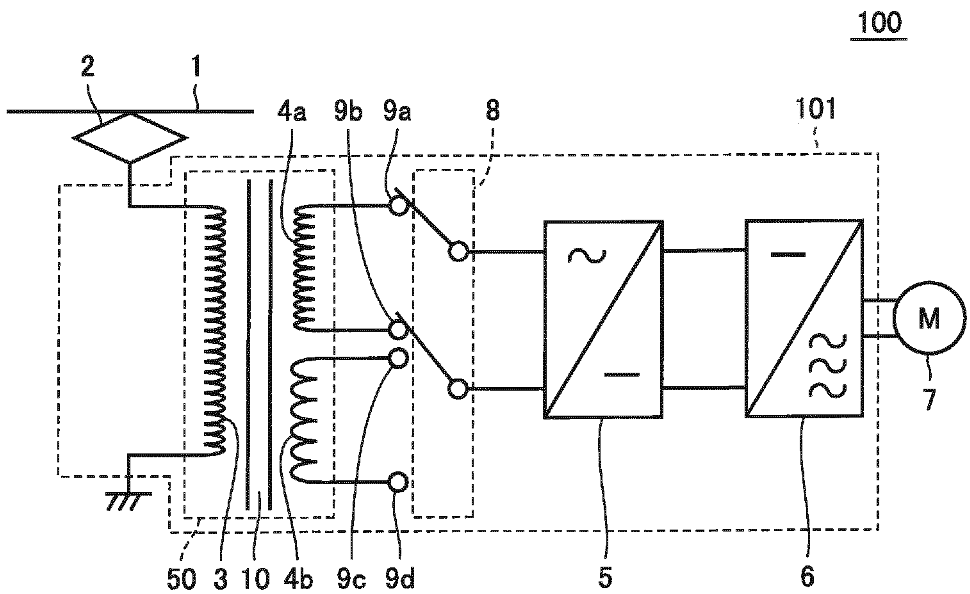

100
2
1
4a
9b
9a
8
101
M
7
50
3
10
4b
9c
9d
5
6

FIG.5

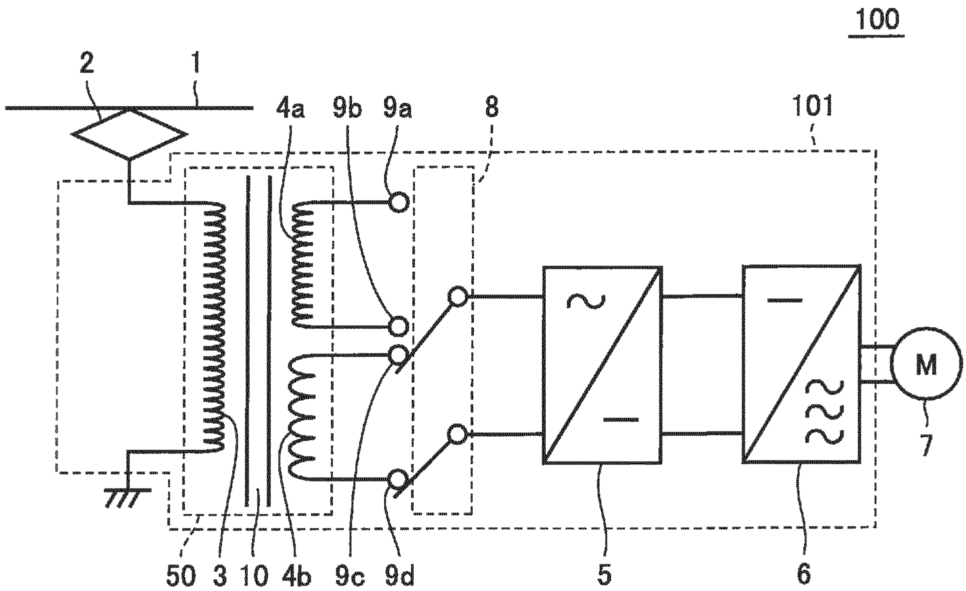
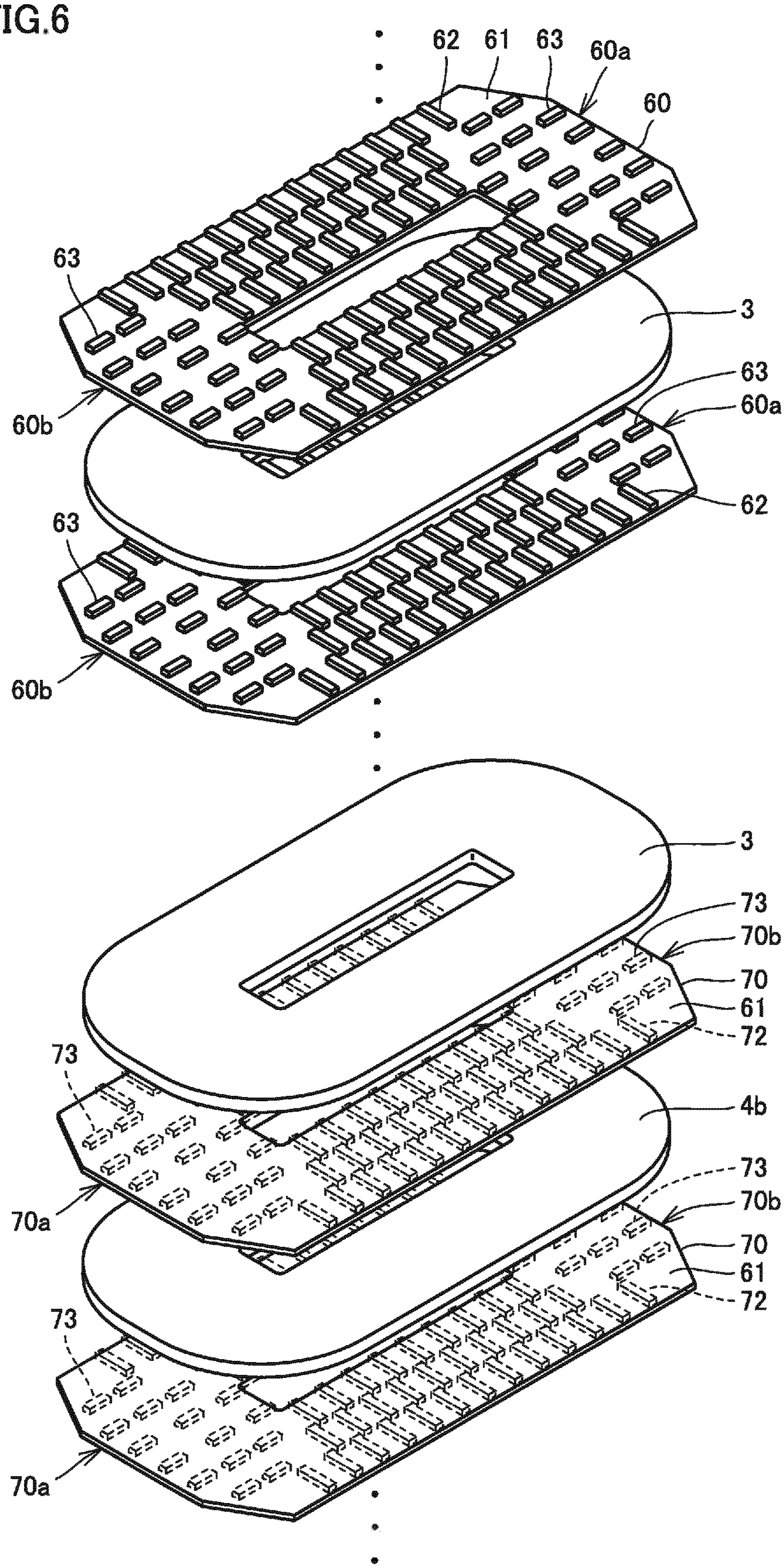


FIG.6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60a
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63
3
63
60a
60b
62
63
60b
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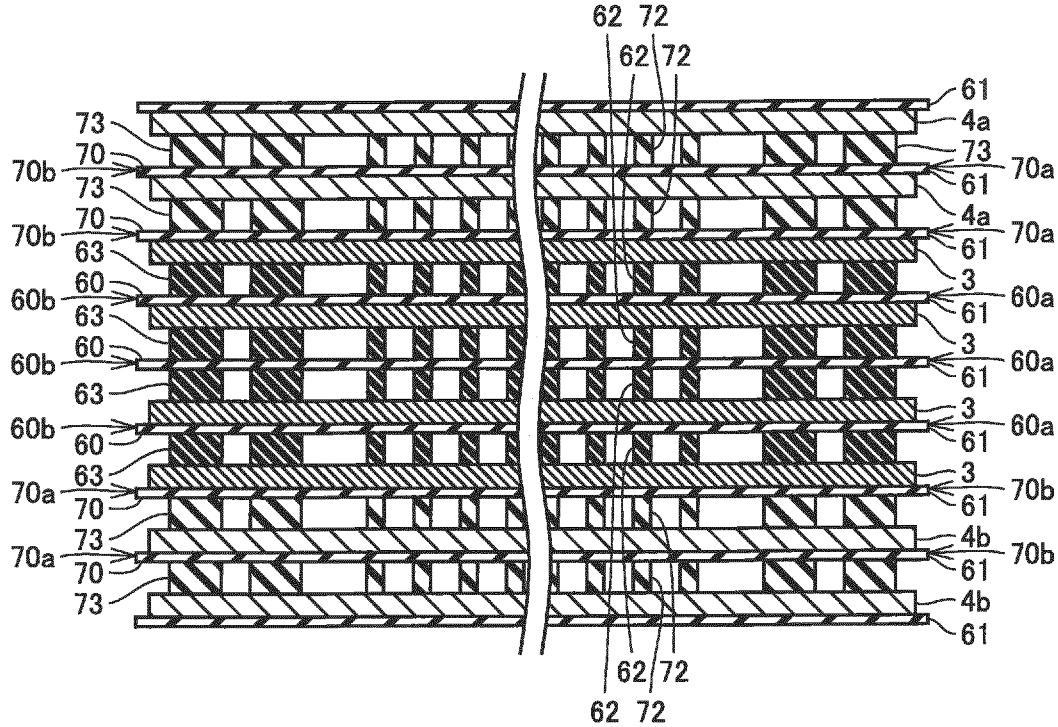
61
72
73
4b
73
70b
70a
70
61
72
73
70a

FIG.7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60a
61
3
70b
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4b
70b
61
4b
61
73
70
70b
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70b
63
60
60b
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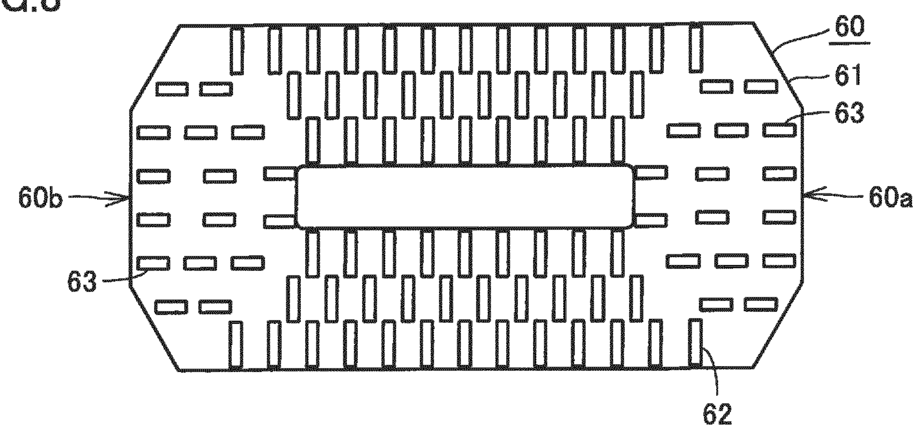
62
72
62
72

FIG.8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60b
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FIG.9

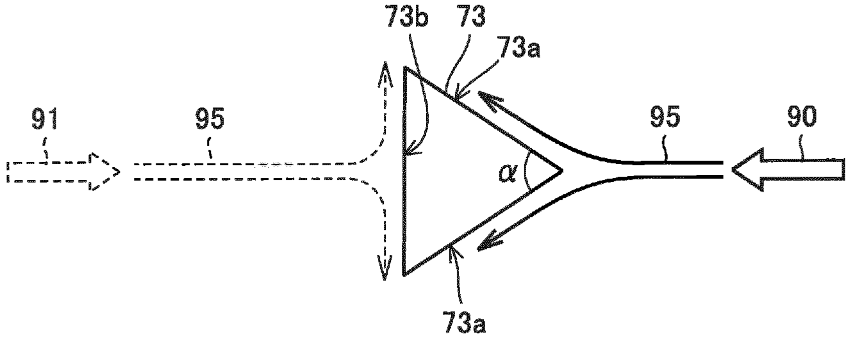


FIG.10

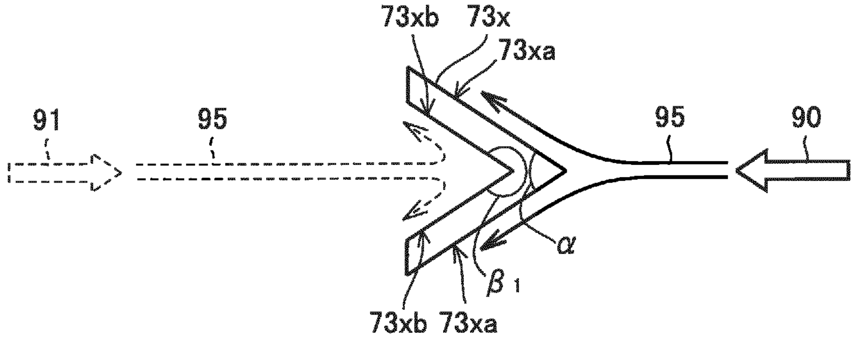


FIG.11

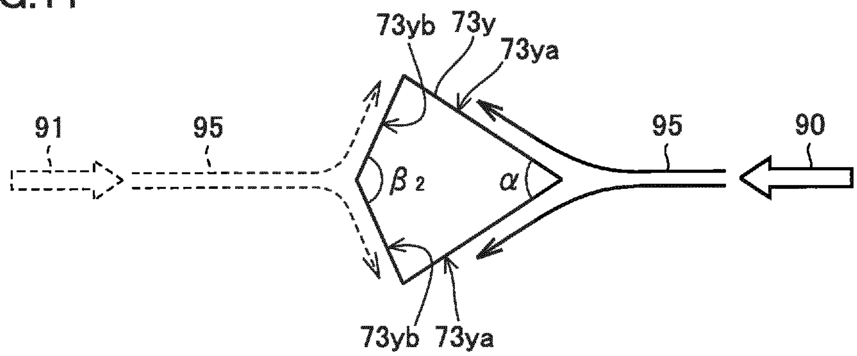
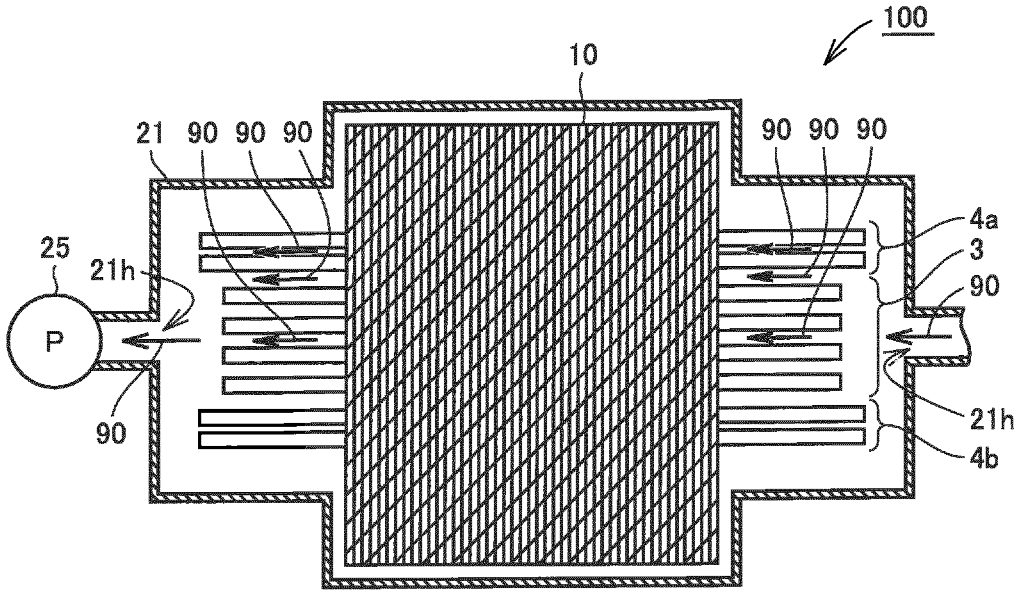


FIG.12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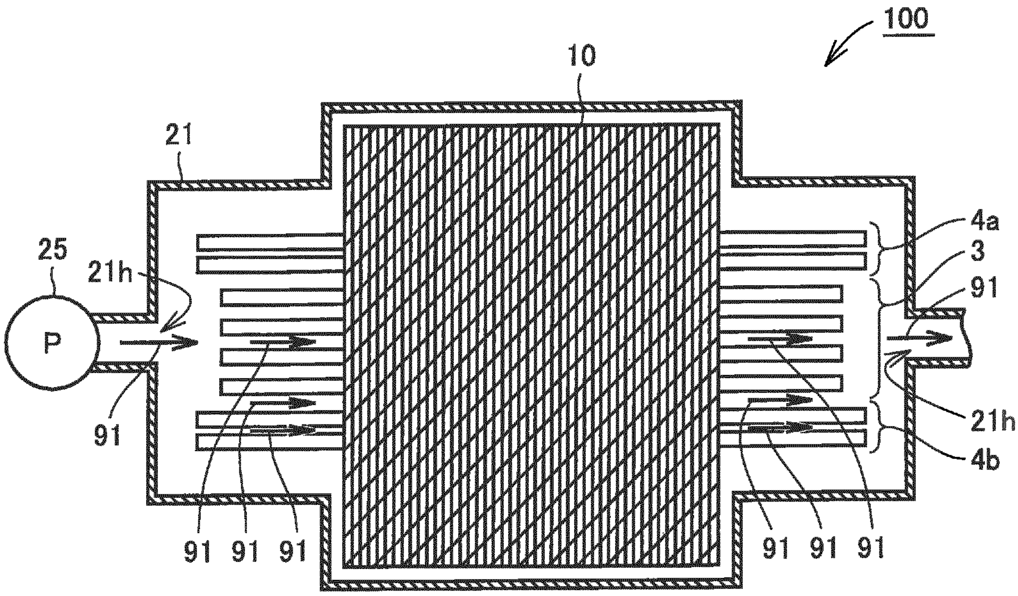
90
90
4a
3
25
21h
90
P
21h
90
4b

FIG.13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21h
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P
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21h
4b
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91
91
91

FIG.14

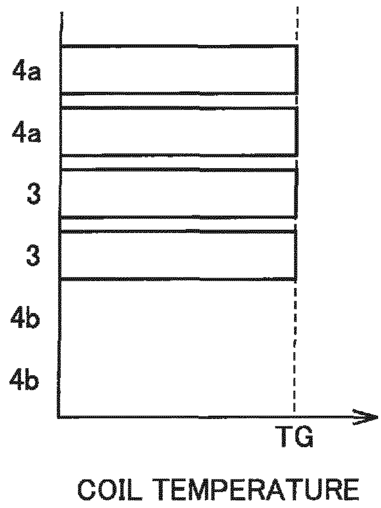
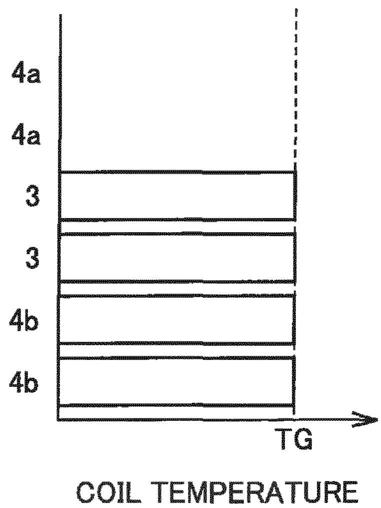

4a
4a
3
3
4b
4b
TG
COIL TEMPERATURE

FIG.15


4a
4a
3
3
4b
4b
TG
COIL TEMPERATURE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/068979

A. CLASSIFICATION OF SUBJECT MATTER
H01F27/12(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

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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2008/007513 A1 (Mitsubishi Electric Corp.), 17 January 2008 (17.01.2008), entire text; fig. 1 to 9 & US 2009/0261933 A1 & EP 2040273 A1 & CN 101473389 A & KR 10-2008-0110835 A & TW 816239 A	1-5

☐ 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
21 January 2015 (21.01.15)	03 February 2015 (03.02.15)

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

Form PCT/ISA/210 (second sheet) (July 2009)

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Patent documents cited in the description

- WO 2010073337 A1 **[0003] [0005]**