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(72) Inventors:
• **TAMURA, Tomoichiro**
Osaka-shi, Osaka 540-6207 (JP)
• **KOMORI, Kou**
Osaka-shi, Osaka 540-6207 (JP)

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(71) Applicant: **Panasonic Corporation**
Kadoma-shi
Osaka 571-8501 (JP)

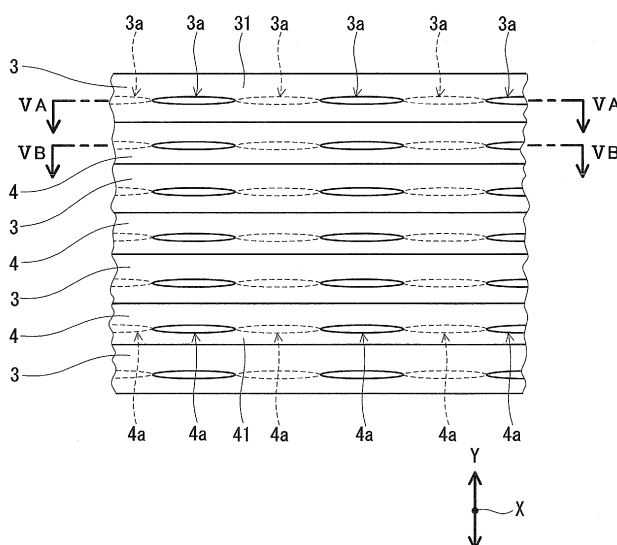
(74) Representative: **Fritsche, Rainer**
Eisenführ, Speiser & Partner
Postfach 31 02 60
80102 München (DE)

(54) **HEAT EXCHANGER**

(57) A heat exchanger includes a heat transfer tube group in which a plurality of first heat transfer tubes (3) through which a first fluid flows and a plurality of second heat transfer tubes (4) through which a second fluid that exchanges heat with the first fluid flows are arranged alternately while being in contact with each other. The heat transfer tube group is formed in a spiral shape by being wound in X direction perpendicular to Y direction

in which the first heat transfer tubes (3) and the second heat transfer tubes (4) are arranged. A plurality of concave portions (3a) are provided on both sides, in the X direction, of an outer circumferential surface (31) of each of the first heat transfer tubes (3), along an extending direction of the first heat transfer tube (3). The plurality of concave portions (3a) form convex portions on an inner circumferential surface of the first heat transfer tube (3).

FIG.4



Description

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger for exchanging heat between a first fluid and a second fluid, particularly to a heat exchanger suitable for heat pump type water heaters.

BACKGROUND ART

[0002] In conventional heat pump type water heaters, air conditioners, floor heating devices, etc., a heat exchanger for exchanging heat between two kinds of fluids (water and a refrigerant, or air and a refrigerant, for example) is used.

[0003] For example, Patent Literature 1 discloses a heat exchanger 10 as shown in FIGs. 10A and 10B. In the heat exchanger 10, one circular water tube 11 through which water flows and two circular refrigerant tubes 12 through which a refrigerant flows are in close contact with each other over their entire lengths, and these tubes 11 and 12 are formed in a track-wound shape. The outer diameter of each of the circular refrigerant tubes 12 is set to be about half of the outer diameter of the circular water tube 11. The two circular refrigerant tubes 12 are disposed at positions at an angle of 45 degrees from the center of the circular water tube 11 with respect to the horizontal line therebetween. Patent Literature 1 also shows in FIG. 4 a heat exchanger unit in which the heat exchangers 10 formed in a track-wound shape are stacked, with a heat insulation sheet being interposed therebetween.

CITATION LIST

Patent Literature

[0004] PTL 1: JP 2006-162204 A

SUMMARY OF INVENTION

Technical Problem

[0005] With a configuration in which the circular water tube 11 and the circular refrigerant tubes 12 are wound while being in contact with each other as in the heat exchanger 10 disclosed in Patent Literature 1, it is possible to ensure a large length of contact among the tubes in a small occupation area. Therefore, the heat exchanger 10 can be downsized more than other heat exchangers having comparable performances. However, even this type of heat exchanger is required to be downsized further.

[0006] Under such circumstances, the present invention is intended to provide a heat exchanger that can be downsized further.

Solution to Problem

[0007] The present invention provides a heat exchanger including a heat transfer tube group in which a plurality of first heat transfer tubes through which a first fluid flows and a plurality of second heat transfer tubes through which a second fluid that exchanges heat with the first fluid flows are arranged alternately while being in contact with each other. The heat transfer tube group is formed in a spiral shape by being wound in a perpendicular direction perpendicular to an arrangement direction in which the first heat transfer tubes and the second heat transfer tubes are arranged. A plurality of concave portions are provided on both sides, in the perpendicular direction, of an outer circumferential surface of each of the first heat transfer tubes, along an extending direction of the first heat transfer tube. The plurality of concave portions form convex portions on an inner circumferential surface of each first heat transfer tube.

Advantageous Effects of Invention

[0008] In the above-mentioned configuration, since both of the first heat transfer tube and the second heat transfer tube constituting the spiral-shaped heat transfer tube group are provided plurally, small-size tubes can be used as these heat transfer tubes. This makes it possible to reduce the minimum bend radius of the heat transfer tube group. Moreover, since the first heat transfer tubes and the second heat transfer tubes are arranged in a direction perpendicular to the direction in which the heat transfer tube group is wound, the width of the row of these tubes also can be kept small. Furthermore, since the first heat transfer tubes and the second heat transfer tubes are arranged alternately while being in contact with each other, a heat transfer tube of one type is sandwiched between heat transfer tubes of the other type, except for the heat transfer tubes located at both side ends. Thus, it is possible to ensure a large contact area between each first heat transfer tube and second heat transfer tube, and accordingly it is possible to shorten the entire lengths of the first heat transfer tube and the second heat transfer tube. With such a configuration, the heat exchanger of the present invention can be downsized further compared to conventional heat exchangers having comparable performances.

[0009] Furthermore, in the present invention, concave portions are provided on both sides, in a direction perpendicular to an arrangement direction in which the first heat transfer tubes are arranged, of an outer circumferential surface of each of the first heat transfer tubes, along an extending direction of the first heat transfer tube. The concave portions form convex portions on an inner circumferential surface of each first heat transfer tube. Therefore, the first fluid flows through the first heat transfer tube while colliding with the convex portions, so that the flow of the first fluid is disturbed. This makes it possible to improve the in-plane temperature uniformity of

the first fluid and enhance the heat exchanging efficiency between the first fluid and the second fluid. As a result, the heat exchanger can be downsized further.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a plan view illustrating a heat exchanger according to one embodiment of the present invention.

FIG. 2 is an enlarged view of an essential part of FIG. 1.

FIG. 3 is an enlarged cross-sectional view of an essential part of FIG. 1, taken along the line III-III.

FIG. 4 is an enlarged side view of an essential part of the heat exchanger illustrated in FIG. 1.

FIG. 5A is a cross-sectional view taken along the line VA-VA in FIG. 4. FIG. 5B is a cross-sectional view taken along the line VB-VB in FIG. 4.

FIG. 6A is a graph showing a relationship between the maximum depth of concave portions of a second heat transfer tube and the flow velocity of a refrigerant near an inner circumferential surface of the second heat transfer tube. FIG. 6B is a graph showing a relationship between the maximum depth of the concave portions of the second heat transfer tube and the pressure loss.

FIG. 7 is an enlarged side view of an essential part of a modified heat exchanger.

FIG. 8 is an enlarged side view of an essential part of another modified heat exchanger.

FIG. 9 is a configuration diagram of a heat pump type water heater including the heat exchanger illustrated in FIG. 1.

FIG. 10A is a plan view illustrating a conventional heat exchanger. FIG. 10B is a cross-sectional view taken along the line XB-XB in FIG. 10A.

DESCRIPTION OF EMBODIMENTS

[0011] Hereinafter, the embodiments for carrying out the present invention will be described in detail with reference to the drawings. A description will be made below with respect to, as an example, a heat exchanger for exchanging heat between water and a refrigerant, such as carbon dioxide and chlorofluorocarbon alternative, used for an apparatus such as a heat pump type water heater. However, the present invention is not limited to this. For example, the present invention is applicable to a heat exchanger for exchanging heat between water and water (hot water), and an internal heat exchanger for exchanging heat between a high temperature refrigerant and a low temperature refrigerant in a heat pump cycle.

[0012] As illustrated in FIG. 1 to FIG. 3, a heat exchanger 1 according to one embodiment of the present invention includes a heat transfer tube group 2 formed in a

spiral shape so as to have a shape of a flat rectangular plate. The heat transfer tube group 2 has a configuration in which a plurality (4 in the example illustrated) of the first heat transfer tubes 3 and a plurality (3 in the example illustrated) of the second heat transfer tubes 4 are joined while being in contact with each other over the approximately entire lengths and are integrated with each other. Relatively low temperature water (a first fluid) flows through the first heat transfer tubes 3 and a relatively high temperature refrigerant (a second fluid) flows through the second heat transfer tubes 4, so that the heat is exchanged between the water and the refrigerant and the water is heated by the refrigerant.

[0013] The first heat transfer tubes 3 and the second heat transfer tubes 4 may be made of metal, such as copper, a copper alloy and SUS, having a satisfactory thermal conductivity. Circular tubes are used suitably as the first heat transfer tubes 3 and the second heat transfer tubes 4.

[0014] As shown in FIG. 3, the first heat transfer tubes 3 and the second heat transfer tubes 4 are arranged alternately in a row in a direction (an up and down direction in FIG. 3) perpendicular to extending directions (central axis directions) of the first heat transfer tubes 3 and the second heat transfer tubes 4, while being in contact with each other. In the present embodiment, the first heat transfer tubes 3 and the second heat transfer tubes 4 are arranged so that their centers lie on the same straight line. One first heat transfer tube 3 and one second heat transfer tube 4 adjacent to each other are joined to each other.

[0015] The joining between the first heat transfer tube 3 and the second heat transfer tube 4 may be performed by brazing, soldering, use of a thermally conductive adhesive, etc. When joined using such a joining agent, the first heat transfer tube 3 and the second heat transfer tube 4 has a large joining area therebetween and can ensure an effective heat transfer area sufficiently. It is also possible to join the first heat transfer tubes 3 and the second heat transfer tubes 4 together by bundling collectively the first heat transfer tubes and the second heat transfer tubes 4 with a heat-shrinkable tube.

[0016] Here, the first heat transfer tubes 3 have preferably an outer diameter D_1 equal to or larger than an outer diameter D_2 of the second heat transfer tubes 4 ($D_2 \leq D_1$). The first heat transfer tubes 3 in the present embodiment have an outer diameter and wall thickness larger than those of the second heat transfer tubes 4. For example, in the case of using carbon dioxide (CO_2) as the refrigerant, the outer diameter D_2 of the second heat transfer tubes 4 is 5.0 mm and the outer diameter D_1 of the first heat transfer tubes 3 is 6.0 mm.

[0017] The heat transfer tube group 2 is wound in a perpendicular direction (hereinafter referred to as "X direction") perpendicular to an arrangement direction (hereinafter referred to as "Y direction") in which the first heat transfer tubes 3 and the second heat transfer tubes 4 are arranged. Specifically, as shown in FIG. 1, the heat

transfer tube group 2 is formed in an approximately-rectangular spiral shape that is wound while repeating alternately a straight portion 2a and a quarter-arc bent portion 2b that smoothly is bent approximately 90°.

[0018] Preferably, a gap S (see FIG. 2 and FIG. 3) is formed between an outer-located winding portion and an inner-located winding portion adjacent to each other, that is, between an n-th portion (n is a natural number) and an n+1-th portion when counting from the outside, in the heat transfer tube group 2. The thus formed gap S can prevent direct heat transfer between winding portions adjacent to each other in the heat transfer tube group 2. As a spacer, a copper tube or a resin sheet, for example, may be disposed at an appropriate location between the outer-located winding portion and the inner-located winding portion adjacent to each other in the heat transfer tube group 2 in order to ensure the gap S. Alternatively, a heat insulating material may be interposed between the winding portions adjacent to each other. In this case, the same advantageous effects also can be obtained as in the case of forming the gap S.

[0019] As shown in FIG. 2, all bend radii R of the bent portions 2b in the heat transfer tube group 2 preferably are uniform. Such a configuration can reduce the number of the types of jigs used in the bending process, improving the workability.

[0020] In the present embodiment, the water flows through the first heat transfer tubes 3 from a peripheral side toward a central side of the spiral shape of the heat transfer tube group 2, and the refrigerant flows through the second heat transfer tubes 4 from the central side toward the peripheral side of the spiral shape of the heat transfer tube group 2. Such a configuration allows the water and the refrigerant to form mutually opposed flows, and thereby the heat is exchanged effectively therebetween.

[0021] Specifically, a first outlet member 6 and a second inlet member 7 are disposed on the central side of the spiral shape of the heat transfer tube group 2, and a first inlet member 5 and a second outlet member 8 are disposed on the peripheral side of the spiral shape of the heat transfer tube group 2. The members 5 to 8 have a rectangular parallelepiped shape extending in the Y direction, and have internal spaces 51, 61, 71 and 81, respectively, at one end surface in the longer direction (the end surface illustrated in FIG. 1). One end of each first heat transfer tube 3 is connected to one side surface of the first outlet member 6, and the other end of each first heat transfer tube 3 is connected to one side surface of the first inlet member 5. One end of each second heat transfer tube 4 is connected to one side surface of the second inlet member 7, and the other end of each second heat transfer tube 4 is connected to one side surface of the second outlet member 8. That is, the first inlet member 5 forms water inlets for guiding water into the respective first heat transfer tubes 3, whereas the first outlet member 6 forms water outlets for discharging collectively the water that has flowed through the first heat transfer

tubes 3. The second inlet member 7 forms refrigerant inlets for guiding refrigerant into the respective second heat transfer tubes 4, whereas the second outlet member 8 forms refrigerant outlets for discharging collectively the refrigerant that has flowed through the second heat transfer tubes 4.

[0022] Furthermore, in the present embodiment, a plurality of concave portions 3a and 4a as shown in FIG. 4, FIGs. 5A and 5B are provided in a specified region E₁ of each longer-side straight portion 2a and a specified region E₂ of each shorter-side straight portion 2a in the heat transfer tube group 2 illustrated in FIG. 1. In this way, the concave portions 3a and 4a preferably are provided avoiding the bent portions 2b when the bend radii R of the bent portions 2b are small. Thereby, damages during the bending process can be prevented. Here, the specified regions E₁ and E₂ each may be across the entire length of the corresponding straight portion 2a or may be narrower than this. Alternatively, the lengths of the specified regions E₁ and E₂ may decrease toward the inner side of the spiral shape. Moreover, the concave portions 3a and 4a do not need to be provided on both of the longer-side straight portions 2a and the shorter-side straight portions 2a, and may be provided to either the longer-side straight portions 2a or the shorter-side straight portions 2a.

[0023] Specifically, in the specified regions E₁ and E₂, the plurality of concave portions 3a are provided on both sides, in the X direction, of an outer circumferential surface 31 of each of the first heat transfer tubes 3 at a specified pitch along the extending direction of the first heat transfer tube 3. Also, the plurality of concave portions 4a are provided on both sides, in the X direction, of an outer circumferential surface 41 of each of the second heat transfer tubes 4 at a specified pitch along the extending direction of the second heat transfer tube 4. As shown in FIG. 5A, the concave portions 3a provided on the first heat transfer tube 3 form convex portions 3b on an inner circumferential surface 32 of each first heat transfer tube 3. As shown in FIG. 5B, the concave portions 4a provided on the second heat transfer tube 3 form convex portions 4b on an inner circumferential surface 42 of each second heat transfer tube 4. The concave portions 3a need only be provided on both sides, in the X direction, of the outer circumferential surface 31 of each of the heat transfer tubes 3, and the concave portions 4a need only be provided on both sides, in the X direction, of the outer circumferential surface 41 of each of the heat transfer tubes 4, and thus the concave portions 3a and 4a do not necessarily have to be located just lateral to the centers of the heat transfer tubes 3 and 4, respectively. For example, in FIG. 4, the concave portions 3a may be provided at positions upward or downward off the positions just lateral to the center of the heat transfer tube 3, and the concave portions 4a may be provided at positions upwardly or downwardly off the positions just lateral to the center of the heat transfer tube 4.

[0024] In the present embodiment, the concave por-

tions 3a provided on one side, in the X direction, of the outer circumferential surface 31 of each of the first heat transfer tubes 3 and the concave portions 3a provided on the other side, in the X direction, of the outer circumferential surface 31 of each of the first heat transfer tubes 3 are disposed alternately along the extending direction of the first heat transfer tube 3. Likewise, the concave portions 4a provided on one side, in the X direction, of the outer circumferential surface 41 of each of the second heat transfer tubes 4 and the concave portions 4a provided on the other side, in the X direction, of the outer circumferential surface 41 of each of the second heat transfer tubes 4 are disposed alternately along the extending direction of the second heat transfer tube 4. Furthermore, in the present embodiment, the concave portions 3a provided on each first heat transfer tube 3 and the concave portions 4a provided on each second heat transfer tube 4 are linear recesses extending in a direction parallel to the extending direction of the first heat transfer tube 3 or the second heat transfer tube 4.

[0025] For example, when carbon dioxide is used as the refrigerant, the concave portions 4a with a length of 5.0 mm are provided on both sides, in the X direction, of each of the second heat transfer tube 4 at a pitch of 10 mm, and the concave portions 3a with a length of 5.0 mm are provided on both sides, in the X direction, of each of the first heat transfer tube 3 at a pitch of 10 mm. The pitch refers to a center-to-center distance between adjacent concave portions on one side in the X direction. The maximum depths (depths at the lowest points located at the deepest positions) of the concave portions 3a and 4a are 5% or more but 20% or less of the outer diameters of the heat transfer tubes 3 and 4, respectively.

[0026] In order to form the heat transfer tube group 2 with such a configuration, the first heat transfer tubes 3 and the second heat transfer tubes 4 both of which are straight are stacked alternately, these tubes stacked are joined by the above-mentioned method, and then the concave portions 3a and 4a are formed on both sides, right and left, of the heat transfer tube group 2 by pressing, for example. Thereafter, the heat transfer tube group 2 is bent, on the same plane, into an approximately-rectangular spiral shape. Alternatively, it is also possible to bend individually, on the same plane, the first heat transfer tubes 3 and the second heat transfer tubes on which the concave portions 3a and 4a respectively are formed in advance by pressing, etc. into an approximately-rectangular spiral shape and stack them.

[0027] As described above, in the heat exchanger 1 in the present embodiment, since both of the first heat transfer tube 3 and the second heat transfer tube 4 constituting the spiral heat transfer tube group 2 are provided plurally, small-size tubes can be used as these heat transfer tubes. This makes it possible to reduce the minimum bend radius of the heat transfer tube group 2. Moreover, since the first heat transfer tubes 3 and the second heat transfer tubes 4 are arranged in a direction perpendicular to the direction in which the heat transfer tube group 2 is

wound, the width of the row of these tubes also can be kept small. Furthermore, since the first heat transfer tubes 3 and the second heat transfer tubes 4 are arranged alternately while being in contact with each other, a heat transfer tube of one type is sandwiched between heat transfer tubes of the other type, except for the heat transfer tubes located at both side ends. Thus, it is possible to ensure a large contact area between each first heat transfer tube 3 and second heat transfer tube 4, and accordingly it is possible to shorten the entire lengths of the first heat transfer tube and the second heat transfer tube. With such a configuration, the heat exchanger 1 of the present invention can be downsized further compared to conventional heat exchangers having comparable performances.

[0028] Furthermore, in the heat exchanger 1 in the present embodiment, the concave portions 3a are provided on both sides, in the X direction, of the outer circumferential surface 31 of each of the first heat transfer tubes 3, along the extending direction of the first heat transfer tube 3. The concave portions 3a form the convex portions 3b on the inner circumferential surface 32 of each first heat transfer tube 3. Therefore, the water flows through the first heat transfer tubes 3 while colliding with the convex portions, so that the flow of the water is disturbed. This makes it possible to improve the in-plane temperature uniformity of the water and enhance the heat exchanging efficiency between the water and the refrigerant. As a result, the heat exchanger can be downsized further. In addition, since the concave portions 3a are not provided in the Y direction in which the first heat transfer tubes 3 and second heat transfer tubes 4 are in contact with each other but are provided in the X direction, the above-mentioned effects can be obtained without increasing thermal contact resistance of these tubes.

[0029] Moreover, in the present embodiment, the concave portions 4a also are provided on both sides, in the X direction, of the outer circumferential surface 41 of each of the second heat transfer tubes 4, along the extending direction of the second heat transfer tube 4. The concave portions 4a form the convex portions 4b on the inner circumferential surface 42 of each second heat transfer tube 4. Also, the refrigerant flows through the second heat transfer tubes 4 while colliding with the convex portions 4b. Accordingly, the flow of the refrigerant is disturbed as well, so that the heat exchanging efficiency between the water and the refrigerant is enhanced further. As the second heat transfer tubes 4 for the refrigerant, grooved tubes in each of which a plurality of grooves are provided on the inner circumferential surface can be used instead of the circular tubes in each of which the concave portions 4a are provided on the outer circumferential surface 41. However, since such grooved tubes are expensive, the cost may be reduced by using, as in the present embodiment, the circular tubes in each of which the concave portions 4a are provided on the outer circumferential surface 41.

[0030] As shown in FIGs. 10A and 10B, in the heat

exchanger 10 having a track-wound shape, in other words, including a pair of straight portions disposed in parallel so as to face each other and a pair of semicircular arc portions bent 180° so as to connect end portions of these straight portions to each other, a large dead space with a shape of an approximately right-angled triangle is formed outside each semicircular arc portion, making a factor of increasing the occupancy area. In contrast, in the heat exchanger 1 in the present embodiment, since the heat transfer tube group 2 is formed in an approximately-rectangular spiral shape and the bent portions 2b located at corners of the spiral shape have the uniform bend radii R, the bend radius of each bent portion 2b located in the outermost winding portion is significantly smaller than that of the track-wound shape. This makes it possible to reduce the dead spaces formed outside the heat exchanger 1. From another viewpoint, the configuration in the present embodiment is different from the track-wound configuration in that the bend radii of the bent portions 2b do not decrease from the peripheral side toward the central side of the spiral shape. Therefore, the heat transfer tube group 2 can reach near the center of the spiral shape, and thus the dead spaces near the center can be reduced. Moreover, the uniform bend radii R of the bent portions 2b lead to satisfactory workability.

[0031] Furthermore, since small-size tubes can be used as the first heat transfer tubes 3 and the second heat transfer tubes 4 as described above, it is possible to make the bend radii of the bent portions 2b of the spiral-shape heat transfer tube group 2 smaller and reduce further the dead spaces having the shape of an approximately right-angled triangle that are formed outside the heat exchanger 1 by the bent portions 2b.

[0032] Furthermore, in the present embodiment, the first inlet member 5 and the second outlet member 8 are disposed on the peripheral side of the spiral shape of the heat transfer tube group 2, and the first outlet member 6 and the second inlet member 7 are disposed on the central side of the spiral shape of the heat transfer tube group 2. In other words, the relatively low temperature water flows through the first heat transfer tubes 3 from one end located on the peripheral side of the spiral shape toward the other end located on the central side of the spiral shape, and the relatively high temperature refrigerant flows through the second heat transfer tubes 4 from one end located on the central side of the spiral shape toward the other end located on the peripheral side of the spiral shape. That is, when the heat exchanger 1 is observed as a whole, both of the water and the refrigerant flow so that the temperatures thereof increase from the periphery toward the center of the heat exchanger 1, and thereby the high temperature portion from which a large amount of heat is radiated to the outside can be disposed in a small area and the radiation loss can be suppressed more effectively. Moreover, since the viscosity of water lowers as its temperature increases, the configuration in which water flows so that its temperature increases toward the center of the spiral shape is preferable also from the view-

point of pressure loss.

[0033] The inwardly-protruding convex portions 4b of the second heat transfer tubes 4 through which the refrigerant flows have the following effects. Usually, the refrigerant contains an oil, such as PAG (polyalkylene glycol), for lubricating compressors, etc. This causes the flow in each second heat transfer tube 4 to be a two-layer flow, forming an oil film on the inner circumferential surface 42 of the second heat transfer tube 4. In order to maintain a high heat exchanging efficiency, the thickness of the oil film preferably is as small as possible. The convex portions 4b are effective also in reducing the thickness of the oil film. More specifically, the presence of the convex portions 4b increases the flow velocity of the refrigerant near the inner circumferential surface 42, thereby increasing the difference between the velocity of the oil film flowing on the inner circumferential surface 42 and the velocity of the refrigerant. In such a situation, the refrigerant takes away a large amount of the oil from the surface of the oil film, reducing the thickness of the oil film. On the other hand, when the convex portions 4b have an excessively large height, the pressure loss is increased and the performance of the heat exchanger 1 is deteriorated. Therefore, it is preferable to set appropriately the maximum depth of the concave portions 4a and hold the height of the convex portions 4b within a proper range.

[0034] For example, FIGs. 6A and 6B show the results of analyses on the flowability of the refrigerant, which was carbon dioxide, when the maximum depth of the concave portions 4a of the second heat transfer tube 4 was changed. The analyses were made using a software "FULENT 6.3", under the conditions that the refrigerant had a mass flow rate of 650 kg/m²s, a temperature of 60°C and a pressure of 10 MPa, and the oil concentration in the refrigerant was 1.0 mass%. The concave portions 4a with a length of 5.0 mm were provided on both sides, in the X direction, of each of the second heat transfer tubes 4 at a pitch of 10 mm, as shown in FIG. 4. The second heat transfer tubes 4 had an outer diameter of 5.0 mm and an inner diameter of 4.1 mm. Then, a calculation was made in each of the cases where the maximum depth of the concave portions 4a was 0 mm, 0.4 mm, 0.5 mm, and 0.6 mm. 0 mm of the maximum depth of the concave portions 4a indicates that circular tubes having no concave portions 4a were used.

[0035] As shown in FIG. 6A, the flow velocity of the refrigerant near the inner circumferential surface 42 is converged when the maximum depth of the concave portions 4a is in the range of 0.4 to 0.5 mm. This means that the thickness of the oil film is not reduced even if the maximum depth of the concave portions 4a is increased to be more than that. On the other hand, as shown in FIG. 6B, the pressure loss is increased rapidly when the maximum depth of the concave portions 4a is in the range of 0.4 to 0.5 mm. Therefore, it is preferable that the maximum depth of the concave portions 4a is in the range of 0.3 to 0.6 mm, which is slightly wider than the above-

mentioned range in two directions.

[0036] The above-mentioned heat exchanger 1 is used suitably for a heat pump type water heater 200. FIG. 9 shows the heat pump type water heater 200 including the heat exchanger 1 of the present embodiment. The heat pump type water heater 200 has a heat pump unit 201 and a tank unit 203. The tank unit 203 has a hot water reservoir tank 202 for holding the hot water produced in the heat pump unit 201. The hot water held in the hot water reservoir tank 202 is supplied to a hot water tap 204. The heat pump unit 201 includes a compressor 205 for compressing the refrigerant, a radiator 207 that allows the refrigerant to radiate heat, an expansion valve 209 for expanding the refrigerant, an evaporator 211 for evaporating the refrigerant, and a refrigerant tube 213 connecting these devices in this order. The heat exchanger 1 in the present embodiment is used as the radiator 207. In the heat pump unit 201, a positive displacement expander capable of recovering the expansion energy of the refrigerant may be used instead of the expansion valve 209.

[0037] The present invention is not limited to the above-mentioned embodiment and can be modified variously. For example, the number and the outer diameter of the first heat transfer tubes 3 and the second heat transfer tubes 4 can be selected appropriately according to the performance required for the heat exchanger 1 and the types of the first fluid and the second fluid. In addition, the number of windings that the heat transfer tube group 2 makes and the size of its spiral shape also can be determined appropriately.

[0038] Furthermore, the heat transfer tube group 2 does not need to be formed in an approximately-rectangular spiral shape. For example, it may be formed in a circular spiral shape, or in a track-wound shape as shown in FIG. 10A. However, from the viewpoint of the dead space as mentioned above, it is preferable that the heat transfer tube group 2 is formed in an approximately-rectangular spiral shape.

[0039] In the present embodiment, the first heat transfer tubes 3 and the second heat transfer tubes 4 are arranged so that their centers lie on the same straight line. However, when the outer diameter D_1 of the first heat transfer tubes 3 is different from the outer diameter D_2 of the second heat transfer tubes 4, the first heat transfer tubes 3 and the second heat transfer tubes 4 may be arranged so that their outermost points on one side in the perpendicular direction perpendicular to the arrangement direction lie on the same straight line, for example. In this case, the centers of the first heat transfer tubes 3 and the centers of the second heat transfer tube 4 lie in a staggered manner.

[0040] Although the concave portions 3a provided on one side, in the X direction, of the outer circumferential surface 31 of each of the first heat transfer tubes 3 and the concave portions 3a provided on the other side, in the X direction, of the outer circumferential surface 31 of each of the first heat transfer tubes 3 are disposed alter-

nately along the extending direction of the first heat transfer tube 3 in the above-mentioned embodiment, they may be disposed at positions facing each other in the X direction. However, when the concave portions 3a are parallel to the extending direction of the first heat transfer tube 3, since the concave portions 3a thus disposed elongate narrow portions in the first heat transfer tube 3, the concave portions 3a preferably are disposed as in the above-mentioned embodiment. This is also the case with the concave portions 4a provided on the second heat transfer tubes 4.

[0041] Furthermore, as shown in FIG. 7, the concave portions 3a provided on both sides, in the X direction, of the outer circumferential surface 31 of each of the first heat transfer tubes 3 may be linear recesses extending in a direction inclined with respect to the extending direction of the first heat transfer tube 3. The concave portions 4a provided on both sides, in the X direction, of the outer circumferential surface 41 of each of the second heat transfer tubes 4 may be linear recesses extending in a direction inclined with respect to the extending direction of the second heat transfer tube 4. Such concave portions 3a and 4a allow the water or the refrigerant to flow while stirring them effectively. Particularly, in the case where the heat exchanger 1 is used for the heat pump type water heater 200 as shown in FIG. 9, it is preferable that the concave portions 4a provided on the second heat transfer tube 4 through which the refrigerant flows are inclined with respect to the extending direction of the second heat transfer tube 4. In some cases, the refrigerant contains an oil for lubricating the compressor 205, and a relatively large amount of this oil accumulates on the bottom of the second heat transfer tube 4, lowering the heat exchanging efficiency. In such a case, the inclined concave portions 4a could stir the refrigerant and suppress the accumulation of the oil. In the case where the inclined concave portions 3a and 4a are provided on the heat transfer tubes 3 and 4, respectively, the concave portions 3a provided on one side, in the X direction, of the heat transfer tube 3 and the concave portions 3a provided on the other side, in the X direction, of the heat transfer tube 3 may be disposed at positions facing each other in the X direction, and the concave portions 4a provided on one side, in the X direction, of the heat transfer tube 4 and the concave portions 4a provided on the other side, in the X direction, of the heat transfer tube 4 may be disposed at positions facing each other in the X direction, as shown in FIG. 7. Alternatively, the concave portions 3a provided on one side, in the X direction, of the heat transfer tube 3 and the concave portions 3a provided on the other side, in the X direction, of the heat transfer tube 3 may be disposed alternately along the extending direction of the heat transfer tube 3, and the concave portions 4a provided on one side, in the X direction, of the heat transfer tube 4 and the concave portions 4a provided on the other side, in the X direction, of the heat transfer tube 4 may be disposed alternately along the extending direction of the heat transfer tube 4, as shown in FIG. 8.

[0042] Furthermore, the shapes and positions of the concave portions 3a and 4a also can be selected appropriately in combination such that the first heat transfer tube 3 is provided with the concave portions 3a parallel to the extending direction whereas the second heat transfer tube 4 is provided with the concave portions 4a inclined with respect to the extending direction, and that the concave portions 3a provided on both sides of the first heat transfer tube 3 are disposed alternately whereas the concave portions 4a provided on both sides of the second heat transfer tube 4 are disposed at the positions facing each other.

[0043] The concave portions of the present invention do not need to be linear recesses as long as they form convex portions on the inner circumferential surface of each first heat transfer tube or second heat transfer tube. For example, the first heat transfer tube 3 and the second heat transfer tube 4 may be formed in a wave shape meandering in the X direction so that valley portions of the wave shape may serve as the concave portions. That is, the convex portions of the present invention do not need to reduce the cross-sectional area of a space enclosed by the inner circumferential surface of the first heat transfer tube or the second heat transfer tube. The convex portions may be portions protruding inwardly while maintaining the cross-sectional area. However, from the viewpoint of workability, it is preferable that the concave portions of the present invention are recesses, particularly linear recesses extending in a specified direction, forming the convex portions 3b that reduce the cross-sectional area of a space enclosed by the inner circumferential surface of the first heat transfer tube 3 or the second heat transfer tube 4, as in the above-mentioned embodiments.

INDUSTRIAL APPLICABILITY

[0044] The heat exchanger of the present invention is useful as a heat exchanger for a heat pump, particularly as a heat exchanger for a heat pump type water heater. In addition, the present invention is applicable to a heat exchanger for exchanging heat between liquids or between gases.

Claims

1. A heat exchanger comprising a heat transfer tube group in which a plurality of first heat transfer tubes through which a first fluid flows and a plurality of second heat transfer tubes through which a second fluid that exchanges heat with the first fluid flows are arranged alternately while being in contact with each other, the heat transfer tube group being formed in a spiral shape by being wound in a perpendicular direction perpendicular to an arrangement direction in which the first heat transfer tubes and the second heat transfer tubes are arranged,

wherein a plurality of concave portions are provided on both sides, in the perpendicular direction, of an outer circumferential surface of each of the first heat transfer tubes, along an extending direction of the first heat transfer tube, and the plurality of concave portions form convex portions on an inner circumferential surface of the first heat transfer tube.

2. The heat exchanger according to claim 1, wherein the concave portions provided on one side, in the perpendicular direction, of the outer circumferential surface of the first heat transfer tube and the concave portions provided on the other side, in the perpendicular direction, of the outer circumferential surface of the first heat transfer tube are disposed alternately along the extending direction of the first heat transfer tube.
3. The heat exchanger according to claim 1, wherein the concave portions provided on one side, in the perpendicular direction, of the outer circumferential surface of the first heat transfer tube and the concave portions provided on the other side, in the perpendicular direction, of the outer circumferential surface of the first heat transfer tube are disposed at positions facing each other in the perpendicular direction.
4. The heat exchanger according to any one of claims 1 to 3, wherein a plurality of concave portions also are provided on both sides, in the perpendicular direction, of an outer circumferential surface of each of the second heat transfer tubes, along an extending direction of the second heat transfer tube, and the plurality of concave portions form convex portions on an inner circumferential surface of the second heat transfer tube.
5. The heat exchanger according to claim 4, wherein the concave portions provided on one side, in the perpendicular direction, of the outer circumferential surface of the second heat transfer tube and the concave portions provided on the other side, in the perpendicular direction, of the outer circumferential surface of the second heat transfer tube are disposed alternately along the extending direction of the second heat transfer tube.
6. The heat exchanger according to claim 4, wherein the concave portions provided on one side, in the perpendicular direction, of the outer circumferential surface of the second heat transfer tube and the concave portions provided on the other side, in the perpendicular direction, of the outer circumferential surface of the second heat transfer tube are disposed at positions facing each other in the perpendicular direction.
7. The heat exchanger according to any one of claims

1 to 6, wherein the concave portions are linear recesses extending in a specified direction.

8. The heat exchanger according to claim 7, wherein the specified direction is a direction parallel to the extending direction of the first heat transfer tube or the second heat transfer tube. 5
9. The heat exchanger according to claim 7, wherein the specified direction is a direction inclined with respect to the extending direction of the first heat transfer tube or the second heat transfer tube. 10
10. The heat exchanger according to any one of claims 1 to 9, wherein the heat transfer tube group is formed in an approximately-rectangular spiral shape that is wound while repeating alternately a straight portion and a bent portion that is bent approximately 90° with a uniform bend radius. 15
20
11. The heat exchanger according to any one of claims 1 to 10, wherein a gap is formed between an outer-located winding portion and an inner-located winding portion adjacent to each other in the heat transfer tube group. 25
12. The heat exchanger according to any one of claims 1 to 10, wherein a heat insulating material is interposed between an outer-located winding portion and an inner-located winding portion adjacent to each other in the heat transfer tube group. 30
13. The heat exchanger according to any one of claims 1 to 12, wherein the first fluid is heated by the second fluid. 35
14. The heat exchanger according to claim 13, wherein the first fluid is water and the second fluid is a refrigerant. 40
15. The heat exchanger according to any one of claims 1 to 14, wherein both of the first heat transfer tubes and the second heat transfer tubes are circular tubes, and the first heat transfer tubes have an outer diameter equal to or larger than that of the second heat transfer tubes. 45
16. The heat exchanger according to any one of claims 1 to 15, wherein the first fluid flows through the first heat transfer tubes from a peripheral side toward a central side of the spiral shape, and the second fluid flows through the second heat transfer tubes from the central side toward the peripheral side of the spiral shape. 50
55

FIG. 1

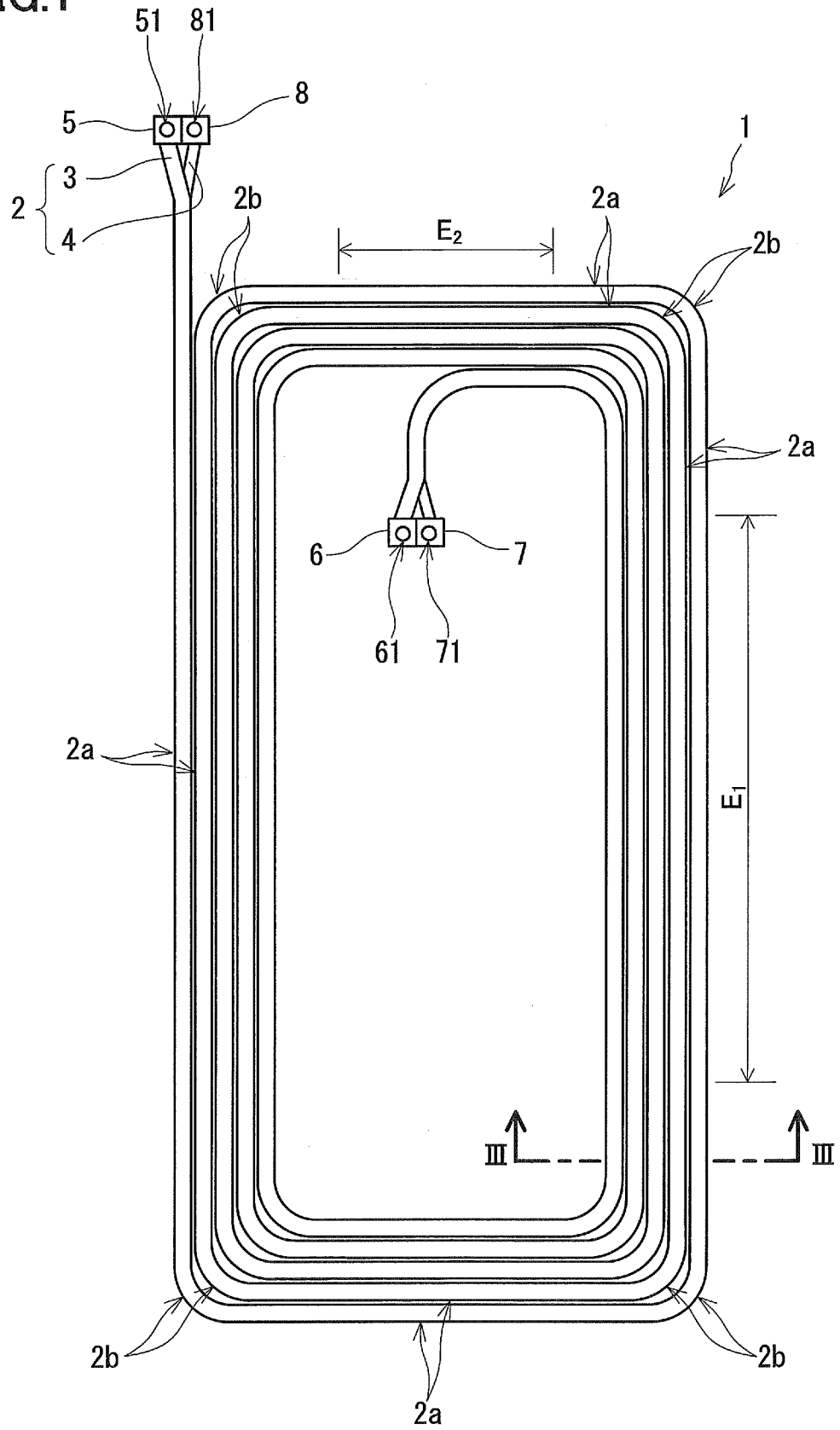


FIG.2

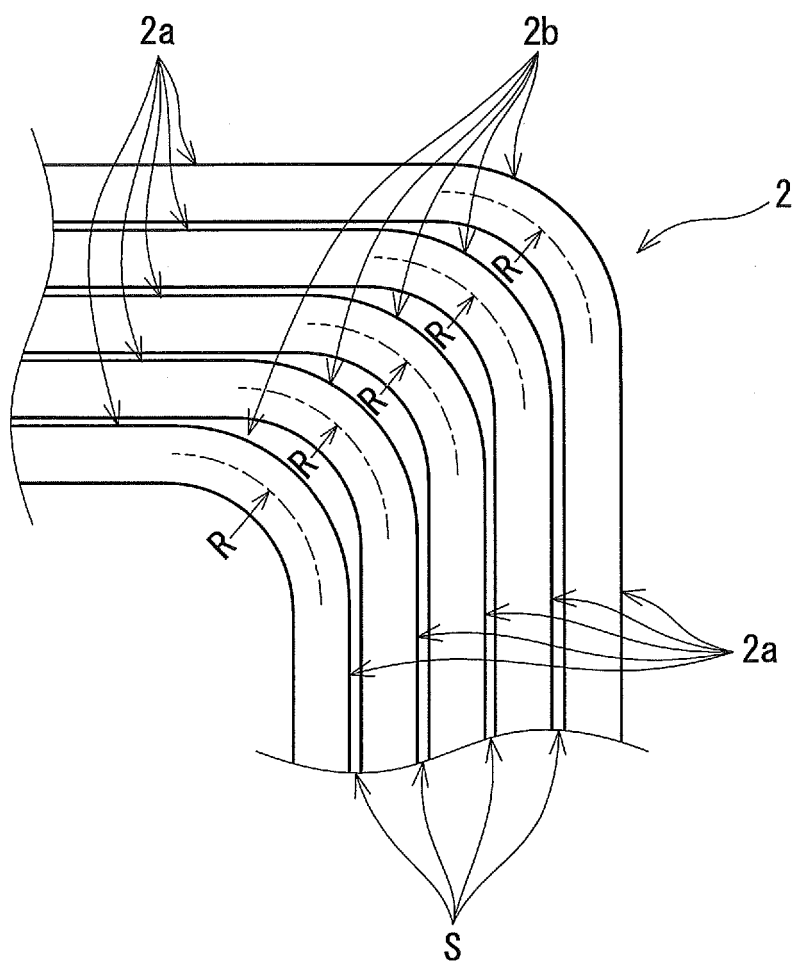


FIG.3

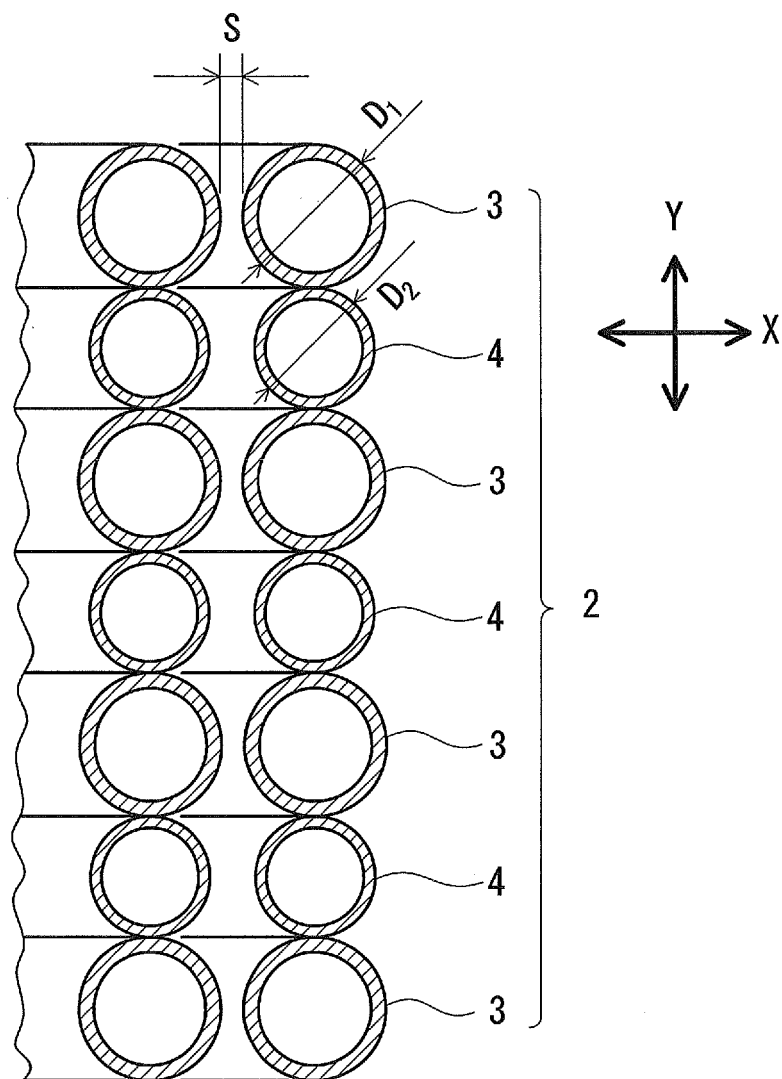


FIG.4

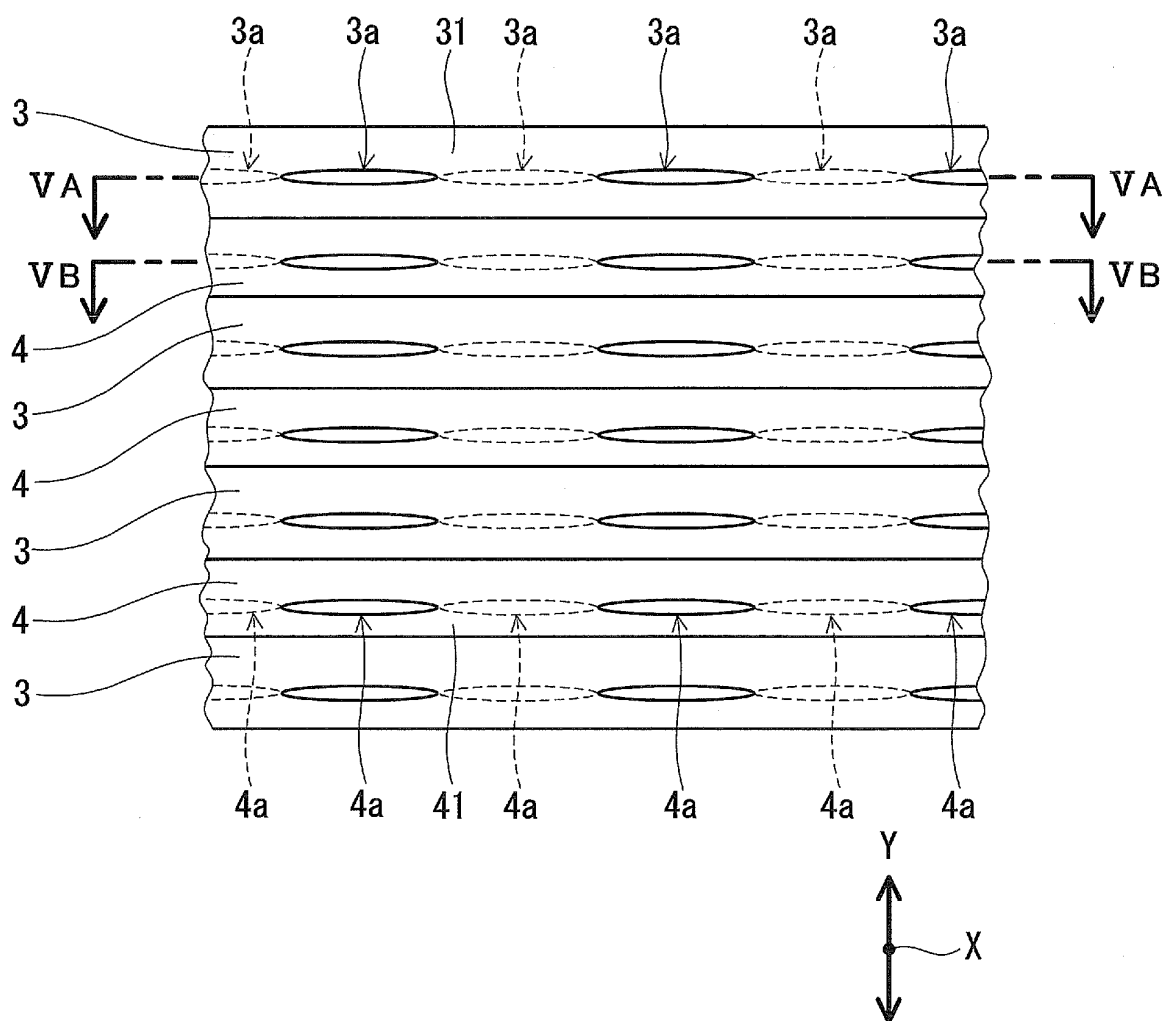


FIG.5A

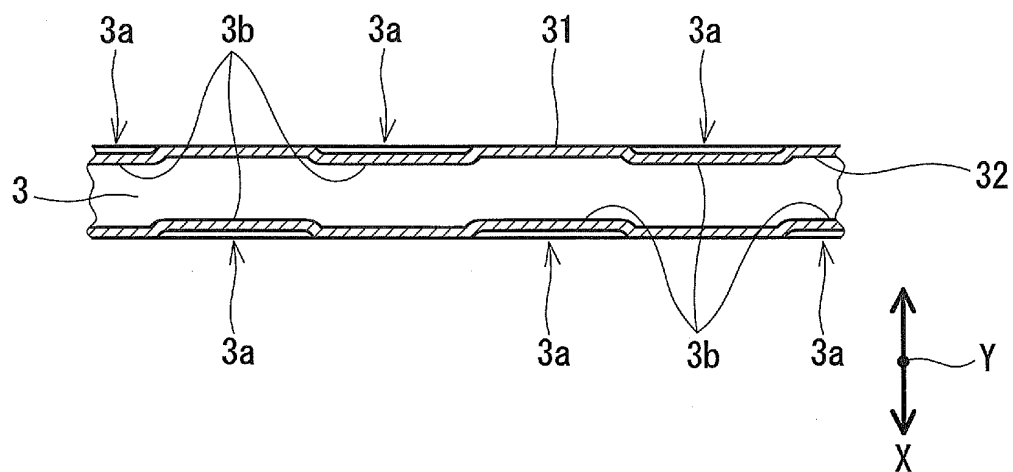


FIG.5B

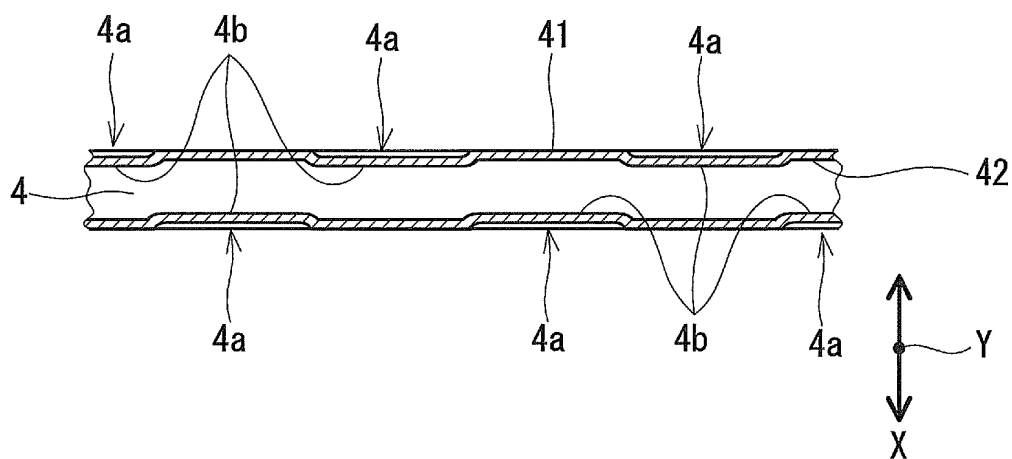


FIG.6A

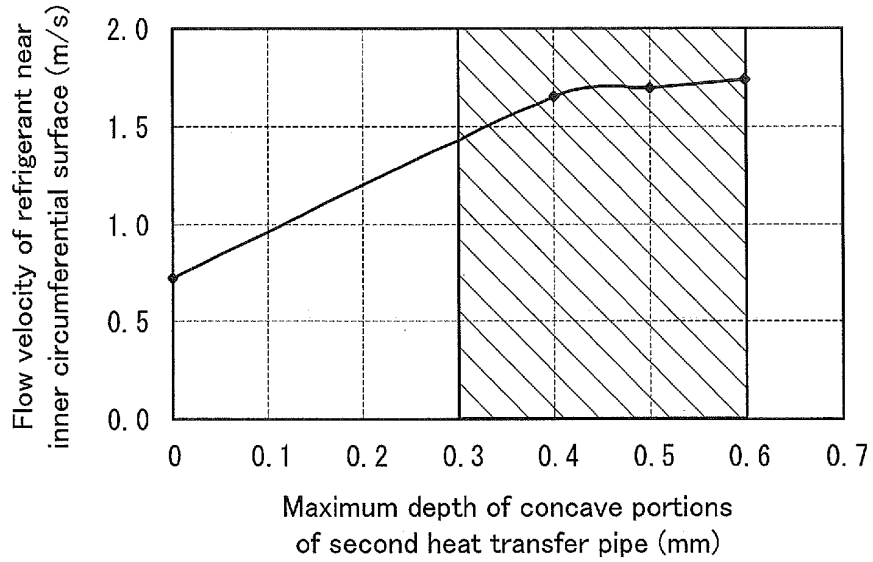


FIG.6B

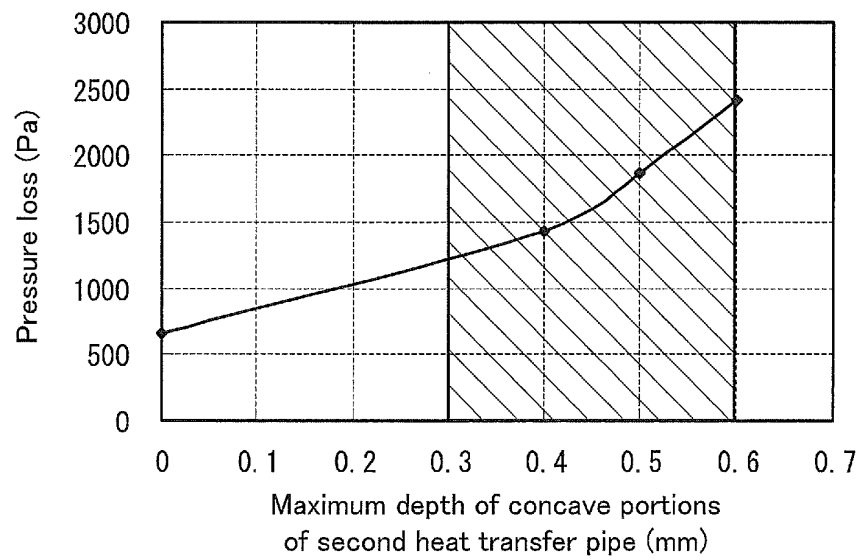


FIG.7

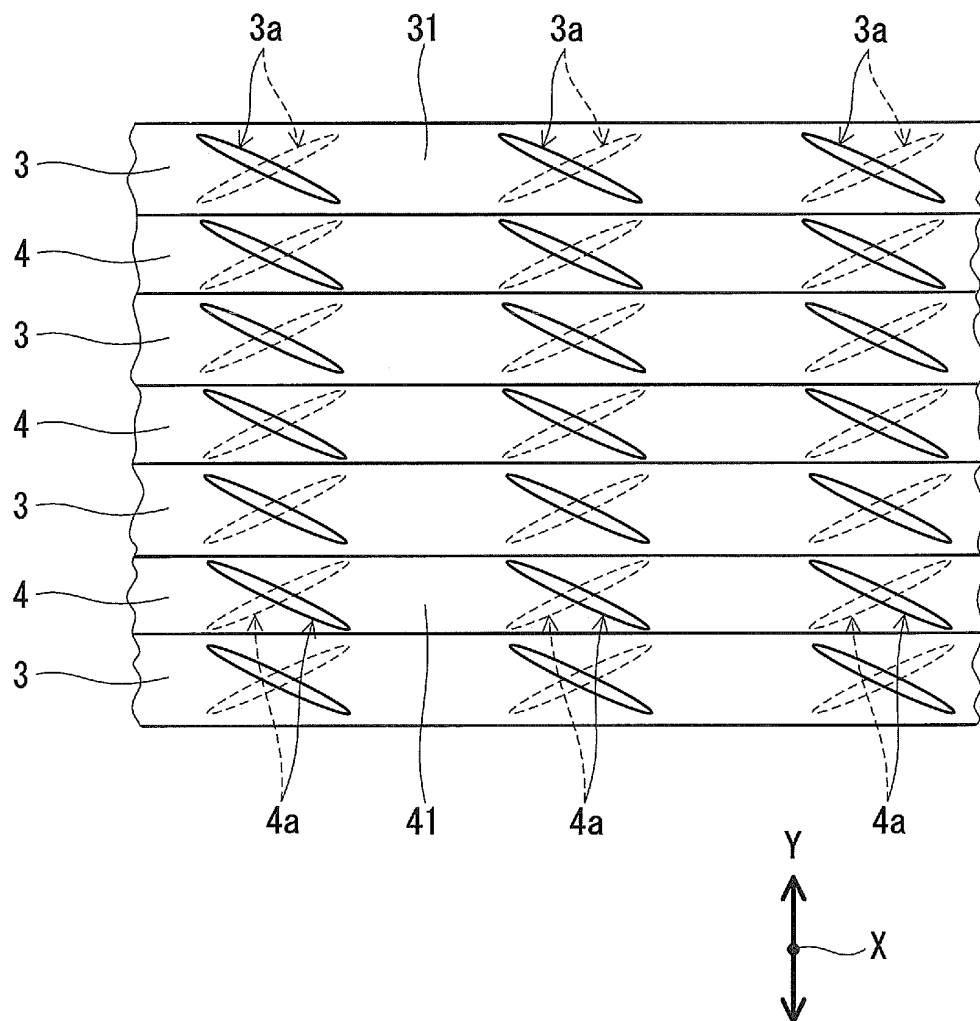


FIG.8

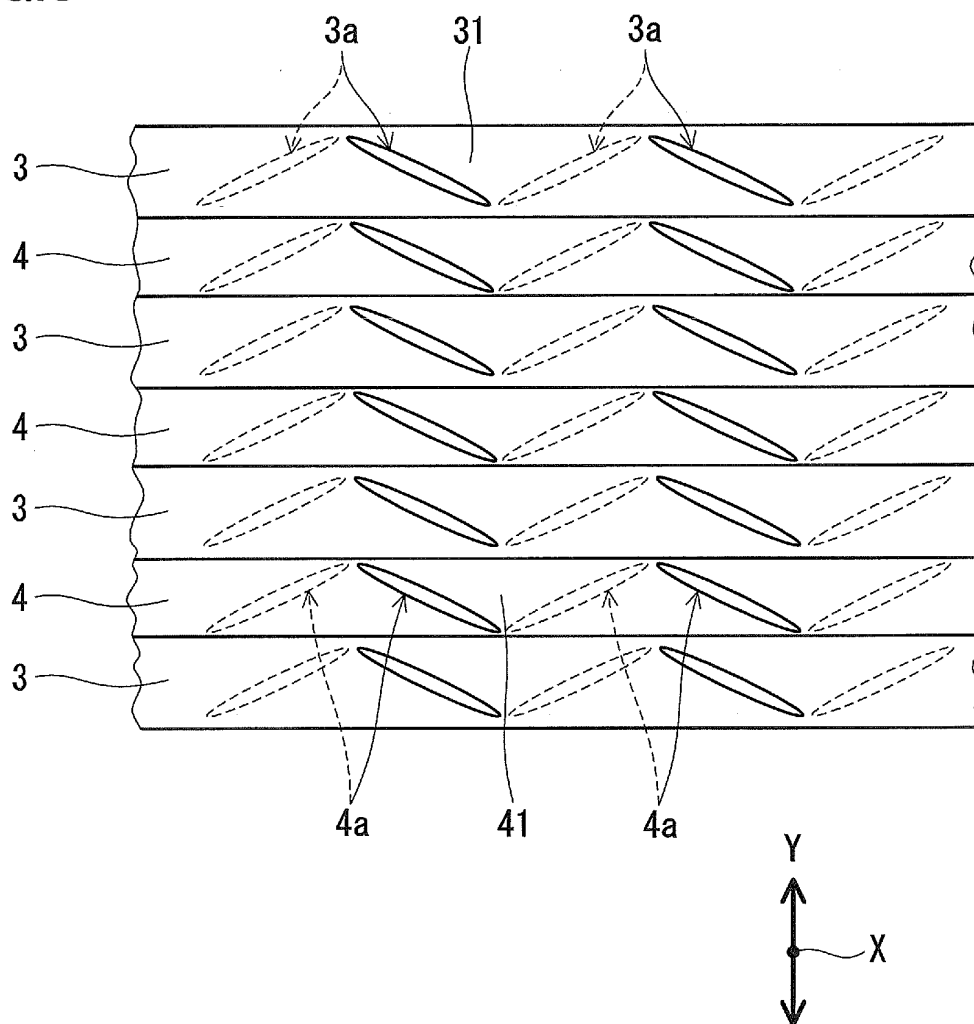


FIG.9

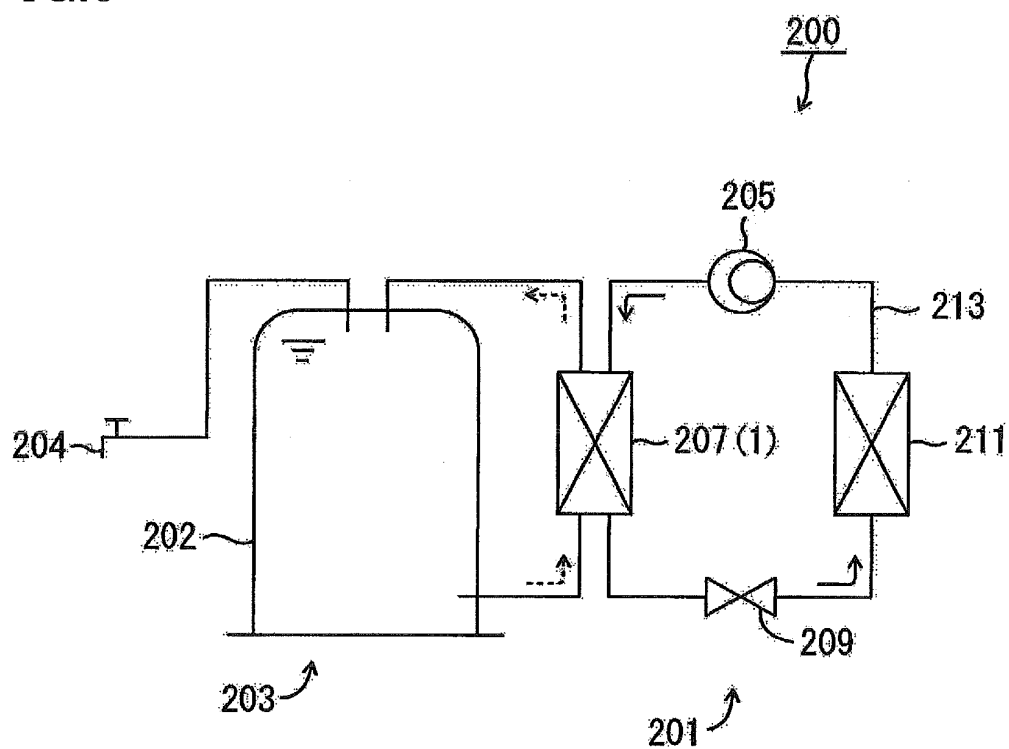


FIG.10A

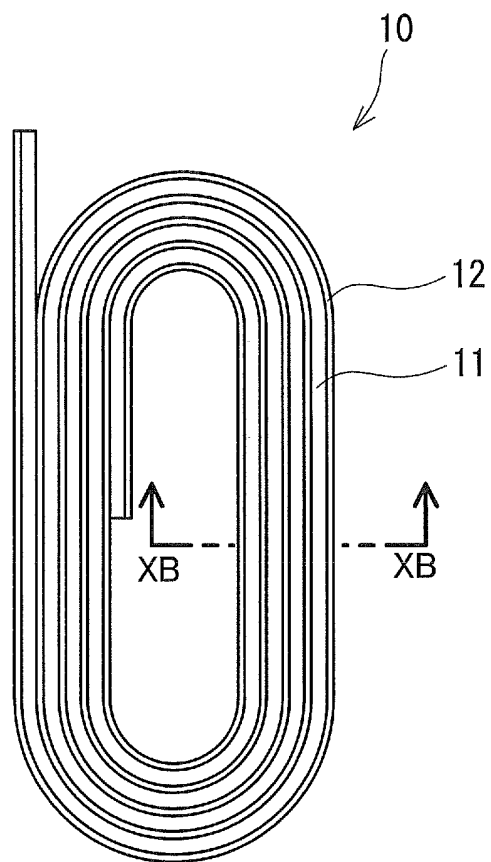
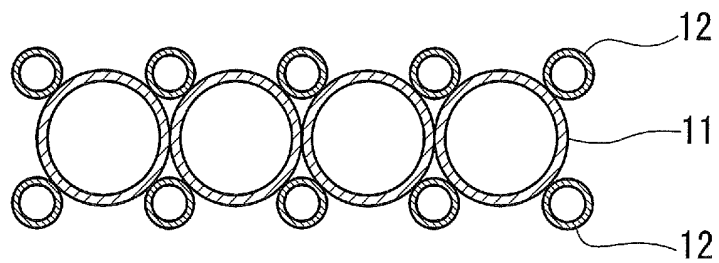


FIG.10B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/000267

A. CLASSIFICATION OF SUBJECT MATTER

F28D7/00 (2006.01) i, F28D7/04 (2006.01) i, F28F1/40 (2006.01) i, F28F1/42 (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)
F28D7/00, F28D7/04, F28F1/40, F28F1/42

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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 3-279788 A (Hitachi Cable, Ltd.), 10 December 1991 (10.12.1991), entire text; fig. 1 (Family: none)	1-16
Y	JP 2005-233479 A (Tokyo Radiator Mfg. Co., Ltd.), 02 September 2005 (02.09.2005), entire text; all drawings (Family: none)	1-16
Y	JP 2005-221094 A (Iwai Kikai Kogyo Co., Ltd.), 18 August 2005 (18.08.2005), entire text; fig. 1 to 3 (Family: none)	3, 6, 8

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

☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search
25 February, 2010 (25.02.10)

Date of mailing of the international search report
09 March, 2010 (09.03.10)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/000267

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6-39463 A (Hitachi, Ltd.), 15 February 1994 (15.02.1994), entire text; fig. 1, 3 (Family: none)	7, 9
Y	WO 2006/103788 A1 (Seika Daigaku), 05 October 2006 (05.10.2006), entire text; all drawings & JP 2009-68838 A & US 2008/0149309 A1 & EP 1873471 A1 & CN 1740729 A & KR 10-2008-0004516 A	10
Y	JP 2007-326141 A (Mitsubishi Electric Corp.), 20 December 2007 (20.12.2007), entire text; all drawings (Family: none)	10
Y	JP 2006-162204 A (Mitsubishi Electric Corp.), 22 June 2006 (22.06.2006), paragraph [0016]; fig. 4 (Family: none)	11-14
Y	JP 2004-226036 A (Toshiba Carrier Corp.), 12 August 2004 (12.08.2004), paragraphs [0034] to [0037]; fig. 3 (Family: none)	15
A	JP 54-128041 A (Hitoshi TATSUMI), 04 October 1979 (04.10.1979), entire text; all drawings (Family: none)	1-16
A	JP 2008-188599 A (Matsushita Electric Industrial Co., Ltd.), 21 August 2008 (21.08.2008), entire text; all drawings (Family: none)	1-16
A	WO 2008/029639 A1 (Seika Daigaku), 13 March 2008 (13.03.2008), entire text; all drawings & US 2009/0250198 A & EP 2071266 A1 & CN 1924507 A & KR 10-2009-0055604 A	1-16

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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