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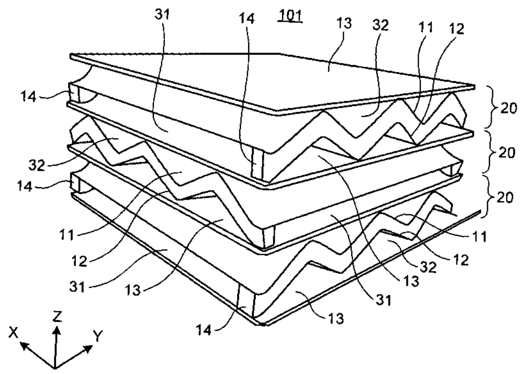
(54) TOTAL HEAT EXCHANGE ELEMENT

(57) A total heat exchange element (101) includes a first flow passage and a second flow passage extending orthogonal thereto. A first fluid and a second fluid are caused to flow through the first and the second flow passages so that sensible heat as well as latent heat are exchanged between the two fluids. The first flow passage is an undulating flow passage (31) that has a rectangular cross section and is formed by positioning a first wave-form plate member (11) shaped in the form of a wave undulating in the layer stacking direction toward the traveling direction of the fluid and a second wave-form plate member (12) shaped substantially in the same form of a wave as the first wave-form plate member (11), on top of each other and with a predetermined interval therebetween, and further causing spacers (14) to hermetically close two lateral portions with respect to the traveling direction of the fluid. The second flow passage is a straight flow passage (32) that has a substantially triangular cross section and is formed between a flat-plate-like member (13) and one of the first and the second wave-form plate members (11, 12), when the flat-plate-like member (13) is positioned on the wave-like form of the one of the first and the second wave-form plate members (11, 12) so as to be in close contact therewith.

FIG.1



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Description

Field

[0001] The present invention relates to a total heat exchange element in which a first fluid and a second fluid (e.g., air) are respectively caused to flow through a first flow passage and a second flow passage that are formed between plate members stacked in the manner of layers so as to extend in directions intersecting each other, so that a total heat exchange process is performed between the two fluids.

Background

[0002] Conventionally, popularly-used total heat exchange elements such as the one described above are provided with partition members that separate the two fluids from each other and spacers that keep the partition members at an interval therebetween, as disclosed in, for example, Patent Literature 1. The partition members have moisture permeability so that a heat exchange process is performed on sensible heat (temperature) and latent heat (humidity) at the same time between the two fluids while using the partition members as a medium. Because an object of such total heat exchange elements is to cause the fluids to perform a total heat exchange process, it is more desirable if the amount of heat exchanged in the element is larger. Total heat exchange elements are more effective than commonly-used heat exchangers (that exchange only sensible heat), because the amount of heat exchanged thereby is larger by an amount corresponding to the exchanged latent heat.

[0003] There are two types of total heat exchange elements such as cross-flow type and counter-flow type. The theoretical amount of exchanged heat per unit volume of the cross-flow type is smaller than that of the counter-flow type; however, the cross-flow type has advantages where, for example, the actual volume to be assembled into an apparatus is smaller, and also, the processing of the element itself is also easier, because the cross-flow type does not require a header (i.e., the part that divides the two fluids used for the total heat exchange process and that introduces the divided fluids into the total heat exchange element flow passages), which is structurally indispensable in the counter-flow type.

[0004] Ideas for how to increase the amount of exchanged heat in a cross-flow type total heat exchange element include a conventional example in which spacers are shaped in the form of corrugated fins so as to make the spacers function as fins and to thereby increase the amount of exchanged heat, as disclosed in, for instance, Patent Literature 2 as a conventional example. To improve the performance thereof, however, the areas of the fins provided in the flow passages need to be enlarged by modifying bending of the fins, as described in, for example, Patent Literature 2. In that situation, because the flow passages are narrowed by the volume of the fins themselves, pressure losses that are caused when the fluids pass therethrough become larger. Also, although the fins have an advantageous effect in the exchange of the sensible heat, the fins have no advantageous effect in the exchange of the latent heat. In fact, because the fins and the partition members are in contact with each other, the areas used for exchanging the latent heat are smaller. As a result, as for total heat exchange elements, improvements on the amount of exchanged heat that are especially realized by using fins are reaching a limit.

[0005] To cope with this situation, as described in Patent Literature 3, 4, and 5, some other ideas for the shapes of the elements that are able to increase the amounts of exchanged heat have been proposed where, for example, heat transfer coefficients of the surfaces of the partition members are improved for the purpose of increasing the amount of exchanged heat, by providing projections or the like that are able to alter the flows, instead of providing the fins.

[0006] Further, as disclosed in Patent Literature 6, 7, and 8, some other ideas have been proposed where the heat transfer area size per unit volume is increased for the purpose of increasing the amount of exchanged heat, by modifying the shapes of the flow passages.

Citation List

Patent Literature

[0007]

Patent Literature 1: Japanese Patent Application Laid-open No. H4-24492
Patent Literature 2: Japanese Utility Model Application Laid-open No. H1-178471
Patent Literature 3: Japanese Utility Model Application Laid-open No. H3-21670
Patent Literature 4: Japanese Patent No. 3805665
Patent Literature 5: Japanese Patent Application Laid-open No. 2008-232592
Patent Literature 6: Japanese Utility Model Application Laid-open No. S58-165476
Patent Literature 7: Japanese Patent No. 3546574

Patent Literature 8: Japanese Utility Model Application Laid-open No. H5-52567

Summary

Technical Problem

[0008] As for the improvements on the heat transfer coefficients of the surfaces of the partition members, however, in many situations, especially in ventilation-purpose total heat exchange elements, the diameters of pipes are small in relation to the flow rates of the fluids so that the flows are in a laminar-flow state where the Reynolds number thereof is smaller (approximately 100 to 1000) than those in other types of heat exchangers. Further, in those regions, the advantageous effect of the improvements on the heat transfer coefficients realized by altering the flows of the fluids themselves is small. For this reason, instead of improving the amount of transferred heat, fins and projections can rather be a cause of a problem where the pressure losses become larger, especially in the regions having a smaller Reynolds number. Having a larger pressure loss is not desirable because the energy consumption of a power device used for forwarding the fluids to the total heat exchange element becomes larger.

[0009] Consequently, it is desirable to adopt, as an alternative, other methods that are able to increase the heat transfer area size per unit volume. However, even if a method that is able to increase the heat transfer area size is used, conventional examples have a problem that can be explained as follows: FIG. 8 is a schematic cross-sectional view for explaining a manner in which dead water regions occur in a flow passage. In conventional examples, there are situations where, when projections and recesses are formed in flow passages with an intention to increase the heat transfer area size, dead water regions (i.e., where the flows do not travel along the surfaces of the partition members and thus become stagnant) D0 occur in the recessed regions. In such situations, even if the heat transfer area size is seemingly increased, the heat transfer area size is, on the contrary, smaller in actuality.

[0010] Speaking of another aspect, in the field of designing apparatuses into which total heat exchange elements are assembled, there has been a demand in recent years for total heat exchange elements of which it is possible to freely determine the outside-diameter without any restrictions, so that it is possible to address various technical issues. To meet this demand, methods have been disclosed, for example, in Patent Literature 4 and 5 where a material is pressed into pieces having an identical shape so that the pieces can be stacked in the manner of layers. According to these methods, however, when it becomes necessary to change the exterior dimension of the total heat exchange elements, it is difficult to address the situation because it is necessary to re-manufacture the pressing mold.

[0011] Further, in other examples of the endeavor to increase the heat transfer area size per unit volume as disclosed in Patent Literature 6, 7, and 8 listed above, because the shapes of the flow passages through which the two types of fluids respectively flow are totally different from each other, the pressure losses are largely different from each other even if the flow rates of the fluids are equal. In that situation, when the element is designed to perform a heat exchange process by using mutually the same type of fluids having mutually different temperatures, such as a total heat exchange element to be used in a ventilation-purpose heat exchanger, the two fluids are caused to flow at a substantially equal flow rate in many examples. Thus, when designing the apparatus into which the element is to be assembled, it becomes necessary to configure, for example, the specifications of the power devices for the fluids flowing in the two flow passages so as to be different from each other, and the designing process can thus be more complicated. For this reason, it is desirable to arrange the pressure losses in the flow passages for the two fluids used for the heat exchange process so as to be as close as possible to each other. In addition, it is desirable if the flow passages have mutually the same shape or similar shapes.

[0012] In view of the circumstances described above, it is an object of the present invention to obtain a total heat exchange element that has a larger heat transfer area size per unit volume without using fins, projections, or the like that can cause obstructions in the flows and without occurrence of dead water regions, and further, the flow passages provided therein are in mutually the same shape and have mutually the same level of pressure loss, the flow passages extending in the two intersecting directions and being configured so that the two fluids performing the heat exchange process on the sensible heat (i.e., the temperature) and the latent heat (i.e., the humidity) flow therethrough. Also, it is another object of the present invention to obtain a total heat exchange element of which, in addition to the characteristics mentioned above, it is easy to change the exterior dimension.

Solution to Problem

[0013] In order to solve the aforementioned problems and attain the aforementioned object, a total heat exchange element according to one aspect of the present invention is constructed in such a manner that a first fluid and a second fluid are respectively caused to flow through a first flow passage and a second flow passage that are formed between plate members stacked in a manner of layers so as to extend in directions intersecting each other, so that sensible heat as well as latent heat are exchanged between the first fluid and the second fluid, wherein the first flow passage is an undulating flow passage that has a rectangular cross section and is formed by positioning a first wave-form plate member that has moisture permeability and is shaped in a form of a wave undulating in a layer stacking direction toward a traveling direction of the fluid and a second wave-form plate member that has moisture permeability and is shaped in a form of a wave undulating substantially in a same cycle as the first wave-form plate member, on top of each other and with a predetermined interval therebetween, and further causing hermetically-closing members to hermetically close two lateral portions with respect to the traveling direction of the fluid, and the second flow passage is a straight flow passage that has a substantially triangular cross section and is formed between a flat-plate-like member having moisture permeability and one of the first and the second wave-form plate members, when the flat-plate-like member is positioned on a wave-like surface of the one of the first and the second wave-form plate members so as to be in close contact therewith.

Advantageous Effects of Invention

[0014] In the total heat exchange element according to an aspect of the present invention, the two surfaces of almost all the areas of the plate members being used have the mutually different fluids flow thereon, and also, the flow passages each have a shape that makes it difficult for dead water regions to occur. As a result, substantially the entirety functions as an effective heat transfer area. Consequently, the heat transfer area size per unit volume is larger, and also, the amount of exchanged heat in the element is larger. Further, in the situation where it is acceptable to keep the amount of exchanged heat equal to that in the conventional example, it is possible to make, conversely, the volume of the element smaller. Thus, it is also possible to contribute to endeavors of saving resources. Further, because the first wave-form plate member, the second wave-form plate member, and the flat-plate-like member are configured by using the material having moisture permeability, it is possible to exchange not only the sensible heat but also the latent heat. Thus, an advantageous effect is achieved where it is possible to increase the amount of exchanged heat in the total heat exchange process.

Brief Description of Drawings

[0015]

FIG. 1 is a perspective view of a total heat exchange element according to a first embodiment of the present invention.
FIG. 2 is a perspective view for explaining directions of fluids flowing through flow passages formed in unit structuring members positioned in mutually different layers.
FIG. 3 is a schematic drawing of an example in which an undulating flow passage has many dead water regions when the height of the flow passage is too high.
FIG. 4 is a schematic drawing of an example in which the flow passage has many dead water regions when a wave-form plate member is folded at apexes.
FIG. 5 is a schematic drawing of an example in which the flow passage has no dead water region when a wave-form plate member is curved at the apexes with an appropriate curvature.
FIG. 6 is a perspective view of a total heat exchange element according to a second embodiment of the present invention.
FIG. 7 is a perspective view of a total heat exchange element according to a third embodiment of the present invention.
FIG. 8 is a schematic drawing of flows for explaining an example in which the flows are not traveling along a wave-form wall surface.
FIG. 9 is a perspective view of a conventional total heat exchange element used for a comparison.

Reference Signs List

[0016]

11 FIRST WAVE-FORM PLATE MEMBER
12 SECOND WAVE-FORM PLATE MEMBER
13 FLAT-PLATE-LIKE MEMBER
14 SPACER
20 UNIT STRUCTURING MEMBER
24, 24a, 24b PARTITION WALL
31 UNDULATING FLOW PASSAGE (i.e., FIRST FLOW PASSAGE)
32 STRAIGHT FLOW PASSAGE (i.e., SECOND FLOW PASSAGE)
101, 102, 103 TOTAL HEAT EXCHANGE ELEMENT
A FIRST FLUID

B SECOND FLUID
DO, D1, D2 DEAD WATER REGION

Description of Embodiments

[0017] In the following sections, exemplary embodiments of a total heat exchange element according to the present invention will be explained in detail, with reference to the accompanying drawings. The present invention is not limited by the exemplary embodiments.

First Embodiment

[0018] FIG. 1 is a perspective view of a total heat exchange element according to a first embodiment of the present invention. To explain the embodiments clearly, the directions are supplementarily described while using the coordinate axes shown in the drawings; however, the present invention is not limited to this example. A total heat exchange element 101 according to the first embodiment is configured so that a plurality of unit structuring members 20 each of which has flow passages formed therein are stacked in the manner of layers while being turned by 90 degrees for each of the layers. Each of the unit structuring members 20 is configured with two wave-form plate members (i.e., a first wave-form plate member 11 and a second wave-form plate member 12) that are each shaped in the form of a wave and has moisture permeability and one flat-plate-like member 13 that has moisture permeability. The total heat exchange element 101 is obtained by stacking, in the manner of layers, the plurality of unit structuring members 20 each of which is made up of the three plate members described above and further adding another flat-plate-like member 13 to an end in the layer stacking direction.

[0019] First, an exemplary configuration will be explained while a focus is placed on the unit structuring member 20 positioned on the uppermost layer in FIG. 1. The first wave-form plate member 11 and the second wave-form plate member 12 are each substantially square and are shaped in the form of waves undulating in mutually the same cycle, by being folded in the thickness direction thereof (i.e., in the layer stacking direction, which is the Z-axis direction) from one side to the opposite side of the square (i.e., toward the direction of the Y-axis), so as to have a zigzag configuration in a cross-section thereof and so as to be generally in the form of the wave. The first wave-form plate member 11 and the second wave-form plate member 12 that are shaped as described above are positioned while being apart from each other by a predetermined distance (i.e., a height of the flow passage) in the layer stacking direction (i.e., the Z-axis direction). The first wave-form plate member 11 and the second wave-form plate member 12 are each processed into a size that matches the flat-plate-like member 13, when being projected onto a flat plane.

[0020] Interposed between the first wave-form plate member 11 and the second wave-form plate member 12 at both ends of the flow passages with respect to the width direction (i.e., both ends with respect to the X-axis direction) are spacers 14 each of which meanders in a zigzag configuration so as to fit the wave-like form, for the purpose of keeping the distance between the first wave-form plate member 11 and the second wave-form plate member 12 and for the purpose of hermetically closing both ends of the space between the first wave-form plate member 11 and the second wave-form plate member 12. Each of the spacers 14 is hermetically fixed to the first wave-form plate member 11 and the second wave-form plate member 12 so that the flowing fluid (i.e., air in the present example) does not leak. In this manner, the parts of the first wave-form plate member 11 and the second wave-form plate member 12 that correspond to the two lateral portions of the flow passage are hermetically closed by the spacers 14, for the entire length with respect to the flow passage direction. As a result, an undulating flow passage (i.e., a first flow passage) 31 that has a rectangular cross section is formed therein.

[0021] The flat-plate-like members 13 are positioned over the top and under the bottom with respect to the layer stacking direction of the first wave-form plate member 11 and the second wave-form plate member 12. (The upper flat-plate-like member 13 is the flat-plate-like member 13 added to the end described above.) The apexes (i.e., the ridges) of the wave-like forms of the first and the second wave-form plate members 11, 12 and the flat-plate-like member 13 are hermetically fixed to each other so that the flowing fluids do not leak. As a result, straight flow passages (i.e., second flow passages) 32 each of which has a substantially triangular cross section are formed between each of the first and the second wave-form plate members 11, 12 and a corresponding one of the flat-plate-like members 13.

[0022] As explained above, each of the unit structuring members 20 has formed therein the undulating flow passage 31 that has a rectangular cross section and that undulates in the layer stacking direction with respect to the traveling direction of the fluid; and the straight flow passages 32 each of which extends orthogonal to the undulating flow passage 31, has a substantially triangular cross section, and extends straight from the entrance to the exit thereof without meandering. Further, the plurality of unit structuring members 20 each of which is configured as described above are stacked in the manner of layers while being turned by 90 degrees for each of the layers, in such a manner that the directions of the waves intersect one another. In the example shown in FIG. 1, three unit structuring members 20 are stacked in the manner of layers along the layer stacking direction (i.e., the Z-axis direction).

[0023] FIG. 2 is a perspective view for explaining the directions of the fluids flowing through the flow passages formed in the unit structuring members 20 positioned in the mutually different layers. Although the reference numerals are omitted from FIG. 2 to keep the drawing easy to see, the configuration is the same as the one shown in FIG. 1.
A first fluid A flowing in the X-axis direction from the right-hand side of FIG. 2 flows through the straight flow passages 32 in the first and the third layers (counted from the bottom) and through the undulating flow passage 31 in the second layer, as shown with a dashed arrow in the drawing. In contrast, a second fluid B flowing in the Y-axis direction from the left-hand side of FIG. 2 flows through the undulating flow passages 31 in the first and the third layers (counted from the bottom) and through the straight flow passage 32 in the second layer. In other words, the structure is arranged so that both the first fluid A and the second fluid B used for performing the heat exchange process on the sensible heat and the latent heat pass through the two mutually-different types of flow passages (i.e., the undulating flow passages 31 and the straight flow passages 32) at the same time. The first fluid A and the second fluid B thus perform the heat exchange process, while using the first wave-form plate members 11, the second wave-form plate members 12, and the flat-plate-like members 13 as a medium having moisture permeability. As explained above, because the flow passages that extend in the two mutually-different directions and through which the fluids used for performing the heat exchange process flow are made up of the two types of flow passages such as the undulating flow passages 31 and the straight flow passages 32 and are in mutually the same shapes, it is possible to arrange the pressure losses in both of the directions so as to be substantially equal.

[0024] FIG. 9 is a perspective view of an example of a conventional total heat exchange element shown for a comparison. A total heat exchange element 201 shown in FIG. 9 is configured so that partition members 213 each of which is in the form of a flat plate and spacers (i.e., corrugated fins) 211 each of which is shaped in such a manner that the cross section thereof is in the form of corrugated fins are stacked in the manner of layers so as to alternate. The layer stacking method being used can be explained as follows: A unit structuring member 220 is prepared by positioning one partition member 213 and one spacer 211 on top of each other in such a manner that the projecting parts of the wave-like forms are in contact, as shown in FIG. 9, and further fixing these members together by adhesion or the like. Unit structuring members 220 each prepared in this manner are stacked in the manner of layers so that the partition members 213 and the spacers 211 alternate and so that the directions in which the openings of the wave-like forms of the spacers 211 are oriented alternate by approximately 90 degrees. (In the example shown in FIG. 9, six unit structuring members 220 are stacked in the manner of layers.) In the total heat exchange element 201, the first fluid A flowing in the X-axis direction from the right-hand side of FIG. 9 and the second fluid B flowing in the Y-axis direction from the left-hand side of FIG. 9 are arranged to flow in the directions intersecting each other in any two adjacently-positioned layers, as shown with a dashed arrow in the drawing. When the two types of fluids are configured so as to pass through the flow passages in this manner, it is possible to perform a heat exchange process between the two fluids, while using the partition members 213 as a medium.

[0025] The first wave-form plate member 11 and the second wave-form plate member 12 according to the first embodiment function as a medium during the heat exchange process and correspond to the partition members 213 in the conventional example shown in FIG. 9.

[0026] The most significant characteristic of the total heat exchange element according to the first embodiment is that the material is not wasted and that the heat transfer area size of the element per unit volume is kept large because almost all the wall surfaces within the element other than the spacers serve as direct heat-transfer areas having the mutually-different heat exchanging fluids flowing on the two surfaces thereof, instead of indirect heat-transfer areas like the fins. Because the fins transfer heat by giving the heat stored therein to the direct heat-transfer area, the area size that contributes to the heat exchange process is not 100 percent of the surface areas of the fins. The fins impact the area size only on the basis of the amounts obtained from the formula "the surface areas of the fins" x "the fin efficiency" including the fin efficiency determined by the shapes of the fins and the circumstances of the surroundings. In contrast, as for the direct heat-transfer areas that are in contact with the mutually-different heat exchanging fluids on the two surfaces thereof, 100 percent of the surface areas thereof are able to contribute to the heat exchange process.

[0027] The heat exchange process explained above refers to the sensible heat, and the fins have almost no impact on the latent heat (i.e., the fin efficiency=0). In fact, because the direct heat-transfer area becomes smaller due to the fins being in contact with the direct heat-transfer area, the amount of exchanged latent heat becomes smaller. For this reason, less material is wasted when the direct heat-transfer area is arranged to be as large as possible.

[0028] When the material is not wasted, it is possible not only to provide the element at a lower cost, but also to reduce the quantity of flat plates required in achieving the same level of performance because the material is used without being wasted. Accordingly, it is also possible to keep large the space volume (i.e., the volume in which the fluids are able to flow) per unit volume. In addition, because the size of the area that is in contact with the fluids is also smaller than in the example where the fins are used, it is ultimately also more advantageous in terms of the pressure losses caused while the fluids are flowing.

[0029] For the first wave-form plate members 11, the second wave-form plate members 12, and the flat-plate-like members 13 according to the first embodiment, a material having moisture permeability is used so that it is possible to exchange the sensible heat as well as the latent heat. Further, ventilation-purpose total heat exchange elements are required to have, at the same time, gas blocking property for preventing the heat exchanging fluids from mixing with each other as well as flame retardant property for ensuring safety. Further, when a total heat exchange element is used for ventilating a space such as a living room where living organisms are present, it is required that the amount of released chemicals that may be harmful to human bodies is small, and more specifically, that the amount of released volatile organic compounds (VOCs) is small. In addition, it is also required that no unpleasant odor is released and that the material strength withstands pressures applied during the processing and the actual use of the element. For these reasons, a material that satisfies the conditions described above is used for the wave-form plate members 11, the second wave-form plate members 12, and the flat-plate-like members 13.

[0030] It is more advantageous when the thickness of these members is smaller in terms of permeability of temperature and moisture. It is also preferable when the thickness of these members is smaller, because it is possible to stack more layers in the same height, when the height of the stacked layers of one unit structuring members 20 is smaller; however, if the thickness is too small, problems may arise where, for example, the material strength is not high enough to withstand the processing. Thus, the thickness should be determined by adjusting the processing method being used and other factors. Generally speaking, a material having a thickness in the range approximately from 20 micrometers to 120 micrometers is popularly used. Further, to satisfy the characteristics described above, some total heat exchange elements are configured so as to have a multi-layer structure instead of a single-layer structure, so that the abovementioned characteristics are distributed to the different layers (i.e., the first layer has moisture permeability, while the second layer has a certain material strength). As long as the abovementioned characteristics are satisfied, it is possible to use any material for the element according to the first embodiment, regardless of the structure of the partition members and the like.

[0031] As for the material for the first wave-form plate members 11, the second wave-form plate members 12, and the flat-plate-like members 13, when a material that has gas blocking property and that contains an alkali metal salt and an alkaline earth metal salt that are water soluble and deliquescent is used, these chemicals store water within the element due to the moisture absorbing action thereof, and at the same time, the chemical liquid diffuses even to the parts where the chemicals were not initially provided because the chemicals dissolve into the stored water. As a result, a problem arises where the amount of chemicals remaining in the partition members, which is needed originally, becomes smaller. In contrast, because the element according to the first embodiment has a structure in which the proportion of the parts other than the partition members is smaller than that in the conventional element, it is possible to ensure a higher level of moisture permeability and a larger amount of exchanged latent heat than the element having the conventional structure and being configured by using the same material.

[0032] Each of the unit structuring members 20 according to the first embodiment is in the form of a flat plate having a substantially square shape; however, each of the unit structuring members 20 may be in the form of a flat plate having a parallelogram shape or a rectangular shape.

<Example 1>

[0033] The total heat exchange element 101 according to the first embodiment shown in FIG. 1 was manufactured in the following manner:

> A piece of specially-processed paper was prepared by applying a moisture-permeable-film forming chemical liquid to one of the surfaces of a piece of paper having a thickness of approximately 100 micrometers, the moisture-permeable-film forming chemical liquid being obtained by dissolving polyvinyl alcohol (PVA), which is a watersoluble high-molecular substance, or the like in water and further mixing in lithium chloride serving as a chemical agent that is water soluble and has a moisture absorbing function and guanidine sulfamate serving as a flame retardant. Another piece of the specially-processed paper prepared in the same manner was processed into a wave-like form with folding creases, was cut into a 120-millimeter square, and was positioned over the abovementioned piece of paper. Subsequently, an aqueous vinyl-acetate resin emulsion adhesive was applied to the apexes of the folding creases of the piece of paper processed into the wave-like form by using a roll coater or the like so as to adhere the pieces of paper together.

[0034] In this situation, by appropriately devising tools being used or the like, the height of the wave-like form was arranged so as to be 1.7 millimeters, whereas the distance between any two adjacently-positioned apexes of the wave-like form was arranged so as to be 11.5 millimeters. After that, the spacers 14 were cut out from thick paper having a thickness of approximately 1.2 millimeters so as to fit the shape of the surface of the wave-like form of the second wave-form plate member 12.
The spacers 14 were positioned over the second wave-form plate member 12 at the end portions thereof. By applying the aqueous vinyl-acetate resin emulsion adhesive described above with the use of a brush, the spacers 14 were adhered to the two sides of the second wave-form plate member 12 extending parallel to the developing direction of the wave-

like form.

[0035] After that, after an adhesive is applied to an upper edge of the spacers 14, another piece of the specially-processed paper that is the same as the one used for the second wave-form plate member 12 and that has a thickness of approximately 100 micrometers was pasted onto the spacers so as to fit the wave-like form thereof, as the first wave-form plate member 11. The height (i.e., the width) of the spacers 14 were determined in such a manner that the distance between the first wave-form plate member 11 and the second wave-form plate member 12 in the layer stacking direction was approximately 1.5 millimeters.

[0036] The unit structuring member 20 was thus produced. A plurality of unit structuring members 20 were prepared in this manner and stacked in the manner of layers while being turned by 90 degrees for each of the layers. The total heat exchange element 101 shown in FIG. 1 was thus obtained.

<Comparison Example>

[0037] In contrast, to make a comparison with the total heat exchange element 101 according to the first embodiment, the conventional total heat exchange element 201 shown in FIG. 9 was produced. In this situation, the wave-like form of the spacers (i.e., the corrugated fins) 211 were shaped so as to be the same as the wave-like forms of the first wave-form plate members 11 and the second wave-form plate members 12 according to the first embodiment. In other words, the height of the wave-like form of the spacers 211 was arranged so as to be 1.7 millimeters, whereas the distance between any two adjacently-positioned apexes of the wave-like form was arranged so as to be 11.5 millimeters.

<Comparison>

[0038] The table shown below indicates results of comparing the direct heat-transfer area sizes when an equal number of layers are stacked for Example 1 and for Comparison Example. In the conventional example, the direct heat-transfer area size is represented only by the areas of the partition members 213 each of which is in the form of a flat plate. In contrast, in the configuration of Example 1, the direct heat-transfer area size is represented by the areas of the flat-plate-like members and the wave-form plate members. Thus, the total heat exchange element 101 according to the first embodiment has an extremely larger direct heat-transfer area size per the same volume.

[0039]

Table 1

	Direct heat-transfer area size (values expressed with comparison example being 1.0)
Example 1	1.37
Comparison example (corrugated fins)	1.0

[0040] When the total heat exchange element 101 according to the first embodiment is produced, it should be noted that, even if the total heat exchange element 101 has a structure with a seemingly large direct heat-transfer area size, there is a possibility that the actual heat transfer area size may have become smaller depending on how the fluids flow in the flow passages and there is a possibility that the expected advantageous effect may not be achieved. These possibilities are significantly higher especially when the undulating flow passages are shaped so as to have a rectangular cross section. For example, if the height of the undulating flow passages is configured to be too high, a phenomenon occurs where, as shown in FIG. 3, the fluid flows only in a straight flow path formed between the upper wave forms and the lower wave forms. In that situation, in actuality, the effect of the heat transfer areas is not realized because the heat is blocked by dead water regions D1 having circling flows, which occur between the wall surface and the fluid (most of which is flowing in the straight flow path) that is supposed to be exchanging the heat. To prevent this situation, it is desirable to configure the distance between the undulating flow passages so as to be smaller than the height of the wave-like forms of the wave-form plate members, because the apexes of the upper wave-form plate members and the apexes of the lower wave-form plate members fit one another in such a manner that no straight flow path is formed, and it is therefore possible to inhibit the dead water regions from occurring.

[0041] Further, in some situations, dead water regions may occur even in curved portions of the undulating flow passages, if any part of the flow gets separated, depending on the flow rates and the shapes of the wave-like forms. FIG. 4 is a drawing of a cross-sectional view of an undulating flow passage having a rectangular cross section in which the apexes formed by the wave-form plate member are sharp. FIG. 5 is a drawing of a cross-sectional view of an undulating flow passage having a rectangular cross section in which each of the apexes formed by the wave-form plate member is shaped with a curvature. FIGs. 4 and 5 depict results of simulations performed by allowing a fluid (i.e., air in the present example) to flow in each of these flow passages at mutually the same flow rate. In the example shown in FIG. 4, fluid circling regions (i.e., dead water regions D2) occur on the downstream-side wall surfaces of the apexes due to a part of the flow that has been separated. As a result, although the wall surfaces that are in contact with the dead water regions D2 are seemingly direct heat-transfer areas, these wall surfaces hardly contribute to the heat transfer in actuality. When the dead water regions D2 occur in this manner, undesirable impacts are made such as a decrease in the heat exchange amount and an increase in the pressure loss.

[0042] As a means for improving this situation, it is possible to adopt a method by which, as shown in FIG. 5, each of the curved portions of the undulating flow passages (i.e., the bending parts including the apexes of the wave-form plate members) is shaped in an arched form having an appropriate curvature, instead of being in a form obtained by folding a plane as explained in the description of the first embodiment.

[0043] Further, the wave-like form of the wave-form plate members may be in any shape as long as the wave-like form is realized; however, it is desirable if the wave-like form is shaped with a sinusoidal curve or is a triangular wave. Alternatively, the wave-like form may be a rectangular wave; however, when the wave-like form is a rectangular wave, there is a possibility that the level of performance may become lower because the areas in which the flat-plate-like members and the wave-form plate members are in contact with each other are larger. In addition, because the fluids passing through the undulating flow passages flow so as to collide with a rising portion of the rectangular wave, an increase in the pressure loss is also anticipated.

[0044] Furthermore, when each of the apexes of the wave-like form is shaped with a curvature, it is possible to provide a total heat exchange element having a smaller pressure loss. By reducing the pressure loss, it is possible to reduce the input of the fluid power device included in the apparatus into which the total heat exchange element is to be assembled, and also, it is thereby possible to contribute to energy saving of the apparatus.

Second Embodiment

[0045] FIG. 6 is a perspective view of a total heat exchange element according to a second embodiment of the present invention. A total heat exchange element 102 according to the second embodiment is configured so that each of the bending parts near the apexes of the first wave-form plate members 11 and the second wave-form plate members 12 is shaped, as shown in FIG. 5, in a smooth arched form having a predetermined curvature so that no dead water region occurs while the fluids are flowing. Also, in the total heat exchange element 102 according to the second embodiment, a plurality of partition walls 24 are provided between the first wave-form plate members 11 and the second wave-form plate members 12 so as to divide each of the undulating flow passages 31 into a plurality of sections with respect to the width direction thereof and so as to enable the first and the second wave-form plate members 11, 12 to support each other. The other configurations are the same as those.in the first embodiment.

[0046] According to the second embodiment, because the plurality of partition walls 24 are provided, the first wave-form plate members 11 and the second wave-form plate members 12 support each other at small intervals. As a result, the number of points in which the first and the second wave-form plate members 11, 12 are held is larger, which enhances the structural strengths of the unit structuring members 20 during the manufacturing process and of the entire total heat exchange element 102. It is therefore possible to improve workability and handleability of the element. Furthermore, the configuration contributes to preventing the two fluids used for the heat exchange process from leaking into each other.

[0047] Further, as an advantageous effect during the manufacture, by designing, in advance, the element with a large exterior dimension that is partitioned by the plurality of partition walls 24, it is possible to obtain total heat exchange elements each having an arbitrary exterior dimension by cutting the large elements into similarly-shaped elements of arbitrary sizes. As a result, it is possible to change the exterior dimension of the elements without the need to change the mold or the like. This characteristic significantly contributes to improvement of the productivity and enhancement of the degree of freedom in designing the product.

Third Embodiment

[0048] FIG. 7 is a perspective view of a total heat exchange element according to a third embodiment of the present invention. A total heat exchange element 103 according to the third embodiment is configured so that partition walls that are provided in the undulating flow passages 31 so as to divide each of the undulating flow passages 31 into a plurality of sections with respect to the width direction thereof are arranged in such a manner that the thickness of the partition wall with respect to the width direction of the flow passage gets larger for one partition wall in every predetermined number of partition walls. In other words, partition walls 24b having the smaller thickness and partition walls 24a having the larger thickness are arranged in a predetermined order. According to the third embodiment, the partition walls 24b having the smaller thickness and the partition walls 24a having the larger thickness are provided so as to alternate. Other configurations are the same as those in the second embodiment.

[0049] In the example according to the second embodiment, although it is possible to obtain elements each having an arbitrary exterior dimension by cutting the large elements into elements of arbitrary sizes, there is a possibility that a large part of the end portions of the obtained elements may be wasted depending on the relationship between the positions of the partition walls and the cutting positions. To cope with this situation, it would be necessary to combine the element with another structure that is able to close a wider portion than that in the conventional example, for the purpose of preventing the fluid from flowing into the end portions of the elements and from leaking into the flow passage of the other fluid. In that situation, it would be difficult to design and prepare the combined structure because it would not be possible to determine the width thereof until the cutting positions of the element are determined. For this reason, although the cutting positions will be limited, by cutting the centers of the thick portions of the partition walls, it is possible to obtain similarly-shaped elements, while ensuring that the elements resulting from the cutting have no wasted part even in the end portions thereof.

Industrial Applicability

[0050] As explained above, the total heat exchange element according to an aspect of the present invention is suitable for an application to a total heat exchange element that performs a heat exchange process on the sensible heat and on the latent heat between two fluids and in which plate members are stacked in the manner of layers. In particular, the total heat exchange element according to an aspect of the present invention is optimal for an application to a total heat exchange element to be assembled into a ventilation apparatus or into an air conditioning apparatus so as to perform an air-versus-air total heat exchange process.

Claims

1. A total heat exchange element in which a first fluid and a second fluid are respectively caused to flow through a first flow passage and a second flow passage that are formed between plate members stacked in a manner of layers so as to extend in directions intersecting each other, so that sensible heat as well as latent heat are exchanged between the first fluid and the second fluid, wherein
   the first flow passage is an undulating flow passage that has a rectangular cross section and is formed by positioning a first wave-form plate member that has moisture permeability and is shaped in a form of a wave undulating in a layer stacking direction toward a traveling direction of the fluid and a second wave-form plate member that has moisture permeability and is shaped in a form of a wave undulating substantially in a same cycle as the first wave-form plate member, on top of each other and with a predetermined interval therebetween, and further causing hermetically-closing members to hermetically close two lateral portions with respect to the traveling direction of the fluid, and
   the second flow passage is a straight flow passage that has a substantially triangular cross section and is formed between a flat-plate-like member having moisture permeability and one of the first and the second wave-form plate members, when the flat-plate-like member is positioned on a wave-like surface of the one of the first and the second wave-form plate members so as to be in close contact therewith.

2. The total heat exchange element according to claim 1, comprising a plurality of unit structuring members stacked in a manner of layers while being turned by 90 degrees for each of the layers, each of the unit structuring members being configured with a set made up of the first wave-form plate member, the second wave-form plate member, and the flat-plate-like member.

3. The total heat exchange element according to claim 1, wherein a difference between a height of a wave-like form of the first wave-form plate member and a height of a wave-like form of the second wave-form plate member is larger than a layer-stacking-direction distance between the first wave-form plate member and the second wave-form plate member.

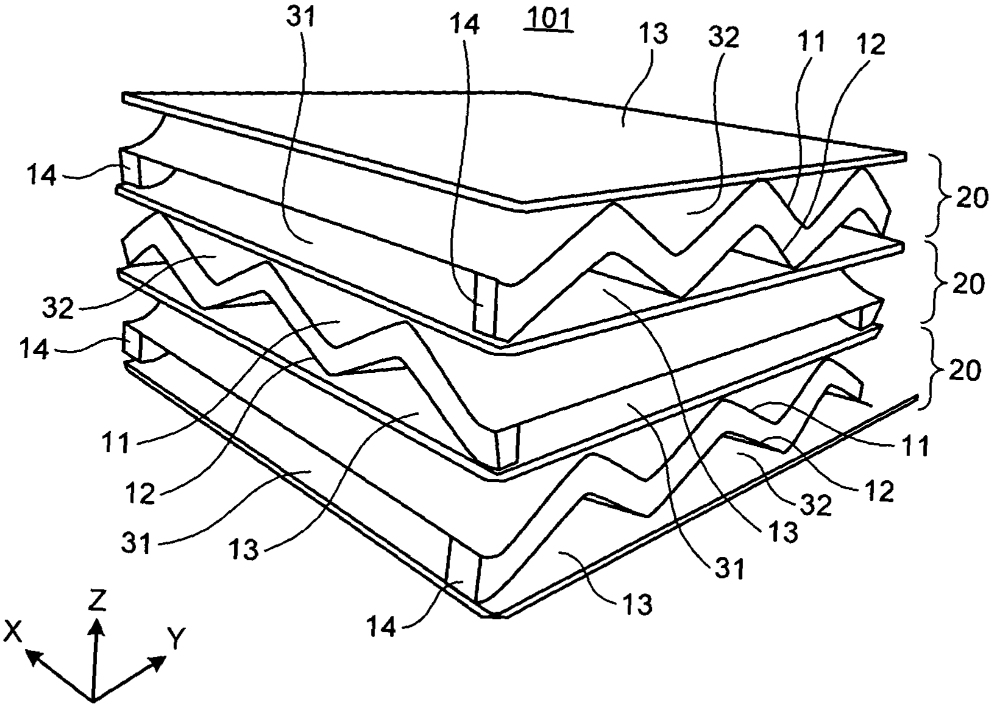
4. The total heat exchange element according to claim 1, wherein each of bending parts at apexes of wave-like forms of the first wave-form plate member and the second wave-form plate member is shaped so as to be in an arched form having a curvature so that no dead water region occurs while the first fluid and the second fluid are flowing.

5. The total heat exchange element according to claim 1, wherein at least one partition wall that divides the undulating flow passage having the rectangular cross section into a plurality of sections with respect to a width direction thereof and that enables the first and the second wave-form plate members to support each other is provided between the first wave-form plate member and the second wave-form plate member.

6. The total heat exchange element according to claim 5, wherein
a plurality of partition walls are provided, and
the partition walls provided in a predetermined position is configured so as to have a larger thickness with respect to the width direction of the flow passage than thicknesses of other partition walls provided in other positions.

7. The total heat exchange element according to claim 1, wherein the first wave-form plate member, the second wave-form plate member, and the flat-plate-like member are configured by using a material that has gas blocking property and that contains an alkali metal salt and an alkaline earth metal salt that are water soluble and deliquescent.

FIG.1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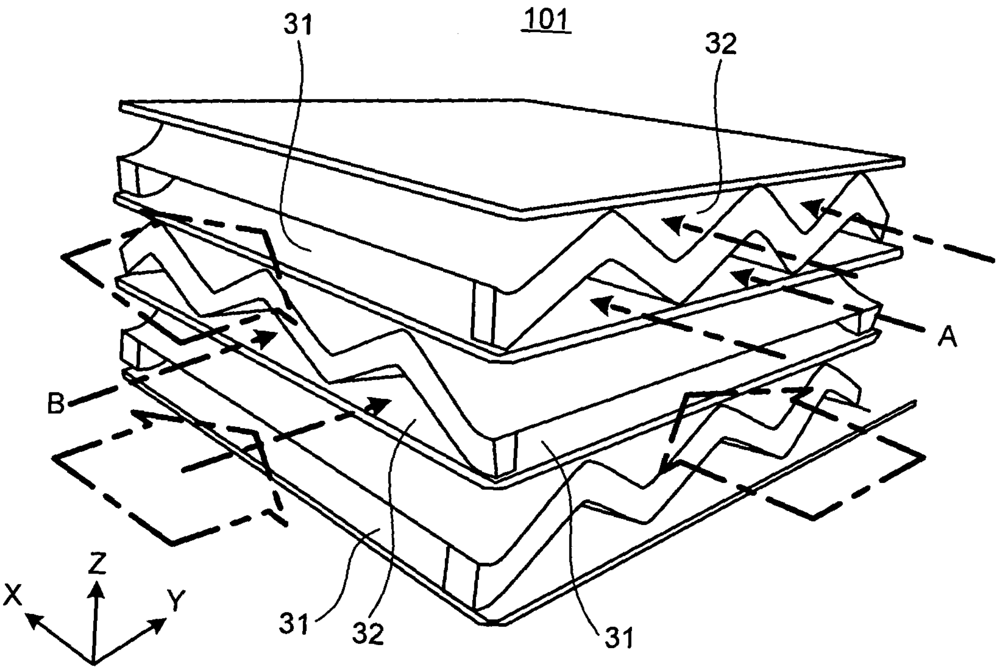
Y

FIG.2


101
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X
Z
Y

FIG. 3

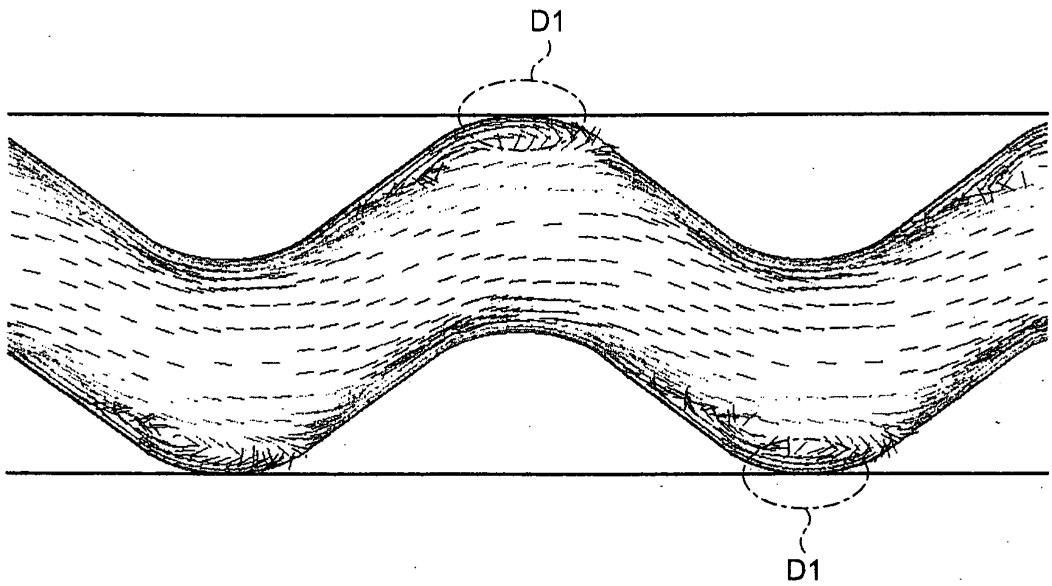

FIG. 4

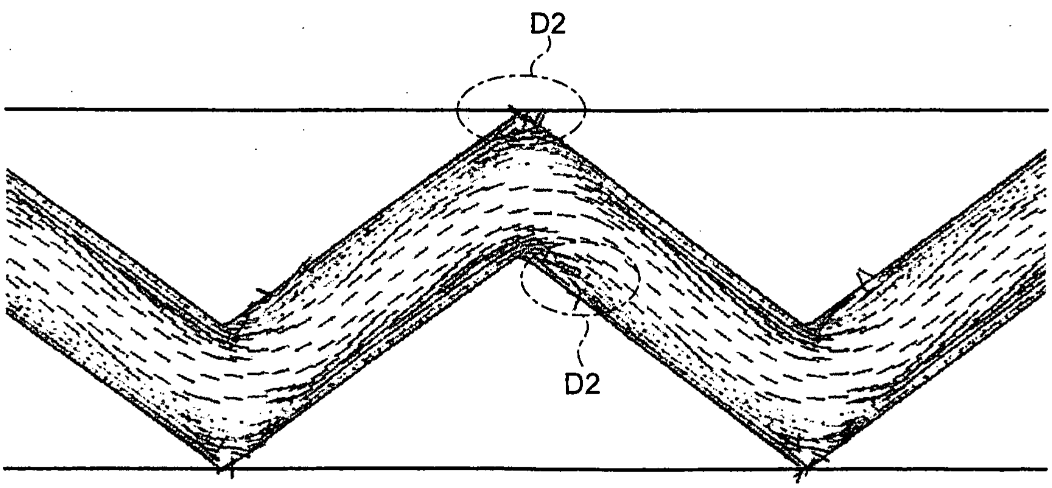

FIG.5

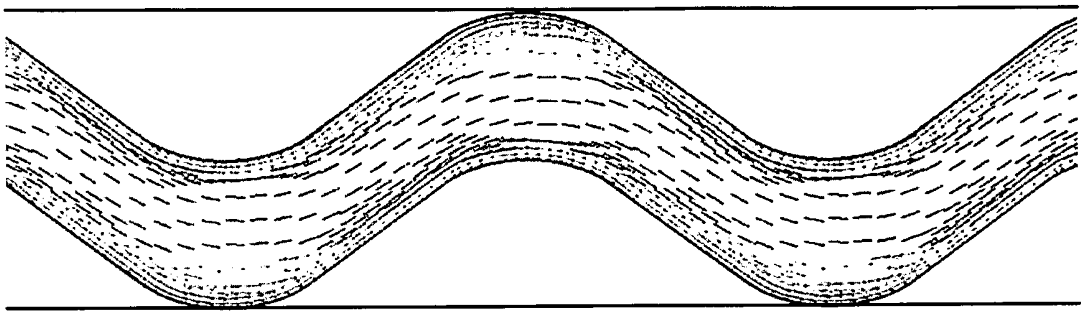

FIG.6

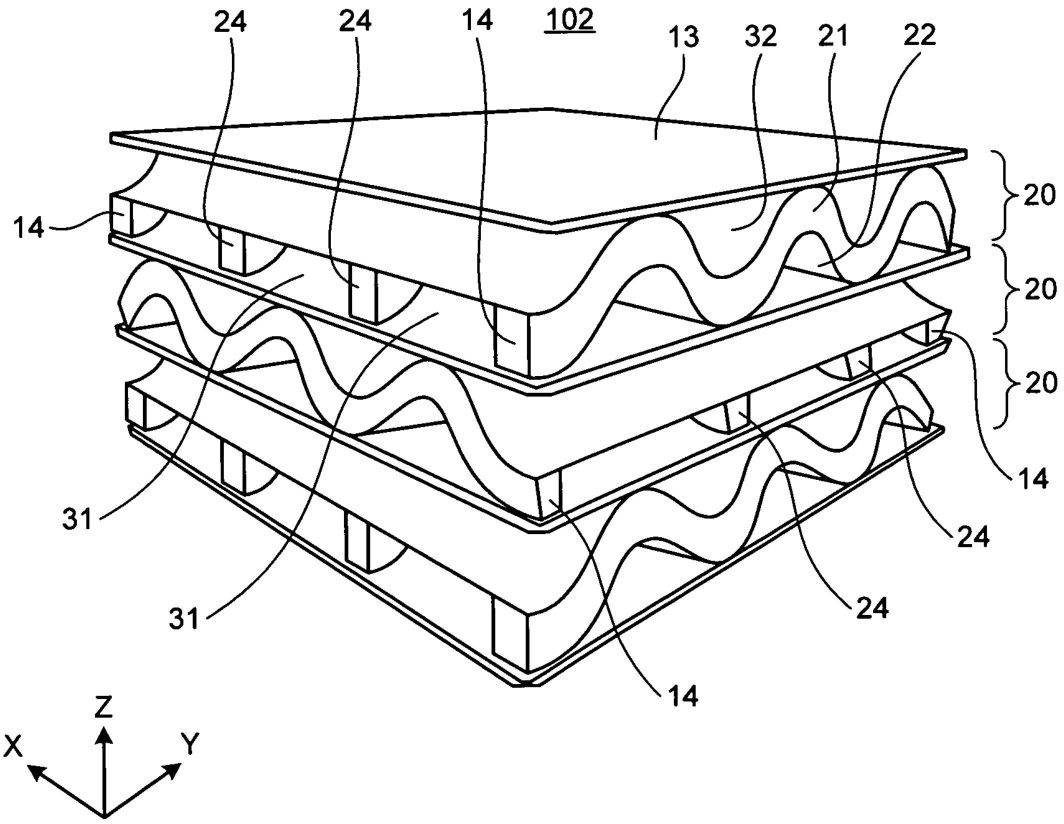

FIG.7

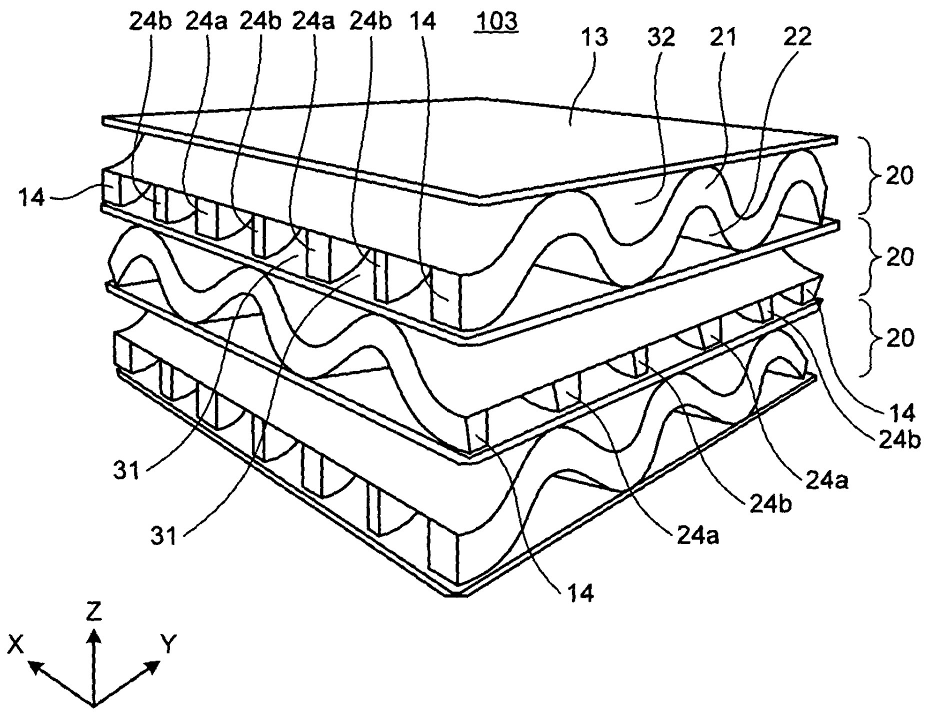
24b 24a 24b 24a 24b 14
103
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FIG.8

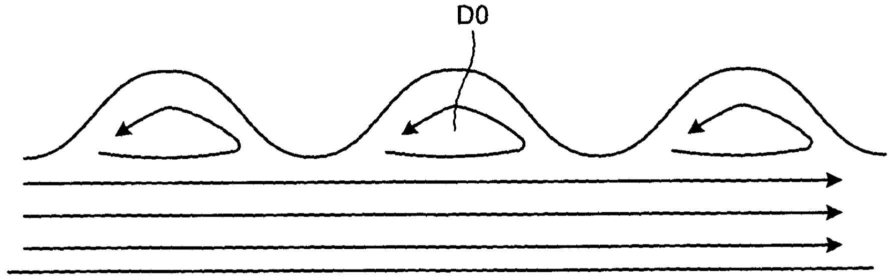
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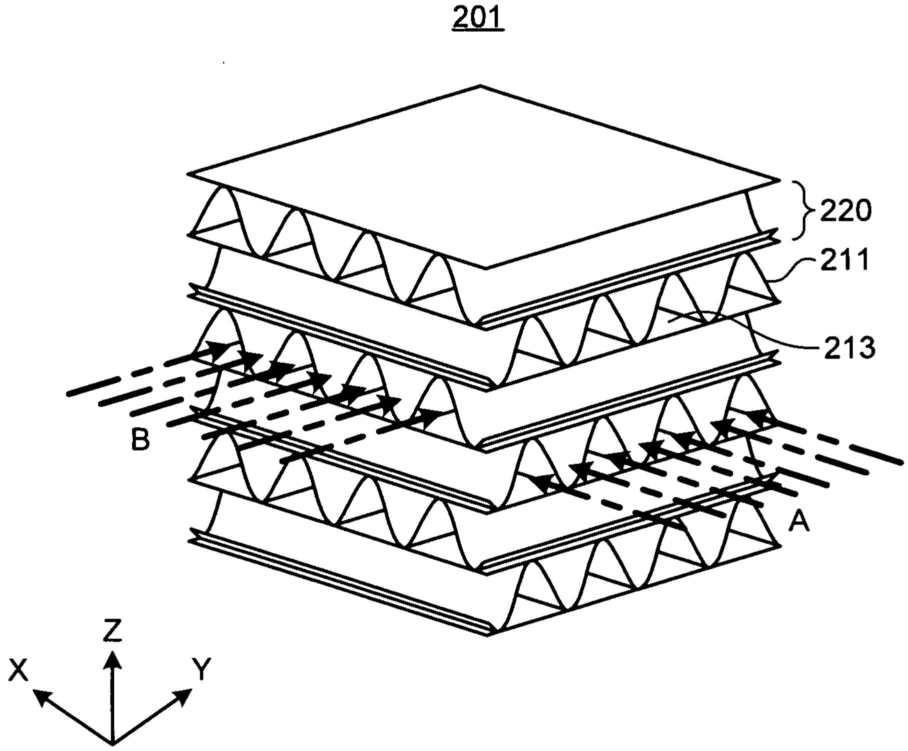
FIG.9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/058362

A. CLASSIFICATION OF SUBJECT MATTER
F28F3/08(2006.01)i, *F28D9/00*(2006.01)i, *F28F3/00*(2006.01)i, *F28F21/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28F3/08, F28D9/00, F28F3/00, F28F21/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2-238293 A (Daikin Industries, Ltd.), 20 September, 1990 (20.09.90), Full text; Figs. 1 to 6 (Family: none)	1,3,5 2,4,6,7
Y	JP 2006-64342 A (Nitta Corp.), 09 March, 2006 (09.03.06), Par. Nos. [0029] to [0078]; Figs. 1 to 3 (Family: none)	2
Y	JP 2000-97590 A (Hisaka Works, Ltd.), 04 April, 2000 (04.04.00), Par. Nos. [0005], [0010] to [0012]; Figs. 2, 3, 6 (Family: none)	4

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 July, 2009 (22.07.09)	04 August, 2009 (04.08.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/058362

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 2001-215093 A (Matsushita Electric Industrial Co., Ltd.), 10 August, 2001 (10.08.01), Par. Nos. [0051] to [0055]; Figs. 4, 5 (Family: none)	4
Y	JP 2005-516171 A (Battelle Memorial Institute), 02 June, 2005 (02.06.05), Par. Nos. [0012] to [0037]; Figs. 5 to 8 & US 2004/0013585 A1 & WO 2003/033983 A2 & CA 2449724 A	6
Y	JP 2007-315649 A (Mitsubishi Electric Corp.), 06 December, 2007 (06.12.07), Par. Nos. [0017] to [0025]; Figs. 1 to 3 (Family: none)	7
A	JP 6-313693 A (Nippan Pakkeji Kabushiki Kaisha), 08 November, 1994 (08.11.94), Par. No. [0019] (Family: none)	1-7
A	JP 63-29195 A (Matsushita Electric Industrial Co., Ltd.), 06 February, 1988 (06.02.88), Page 3, upper right column, lines 4 to 8 (Family: none)	1-7

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/058362

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The search has revealed that the matter common to the inventions of claims 1-7 is described in document 1 (JP 2-238293 A), and therefore the matter is not novel. Accordingly, the common matter is not a special technical feature within the meaning of PCT Rule 13.2, second sentence. The inventions of claims 2 and 3 are exceptionally not subjected to the requirement of unity of invention. The inventions of claims 4-7 have no other matter, which can be considered as a special technical feature within the meaning of PCT Rule 13.2, second sentence, common to the invention of claim 1, (continued to extra sheet)

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest the

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/058362

Continuation of Box No.III of continuation of first sheet(2)

so that no technical relationship within the meaning of PCT Rule 13 between the different inventions can be seen.

Form PCT/ISA/210 (extra sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP H424492 B **[0007]**
- JP H1178471 B **[0007]**
- JP H321670 B **[0007]**
- JP 3805665 B **[0007]**
- JP 2008232592 A **[0007]**
- JP S58165476 B **[0007]**
- JP 3546574 B **[0007]**
- JP H552567 B **[0007]**