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(54) TOTAL HEAT EXCHANGE ELEMENT AND MANUFACTURING METHOD THEREOF

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(57) ABSTRACT

A total heat exchange element has a stacked-layer structure in which sheet-like partition members added a water-soluble moisture absorbent thereto and spacing members are stacked alternately, the spacing members are joined with the partition members by using an adhesive so as to form air flow passages together with the partition members. According to the present invention, the spacing members have water retention properties. Further, an adhesive that exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent is used as the adhesive. As a result, it is easy to obtain a total heat exchange element with which it is possible to easily constitute an air-conditioning apparatus or a ventilator that has high latent heat exchange efficiency and has high reliability.

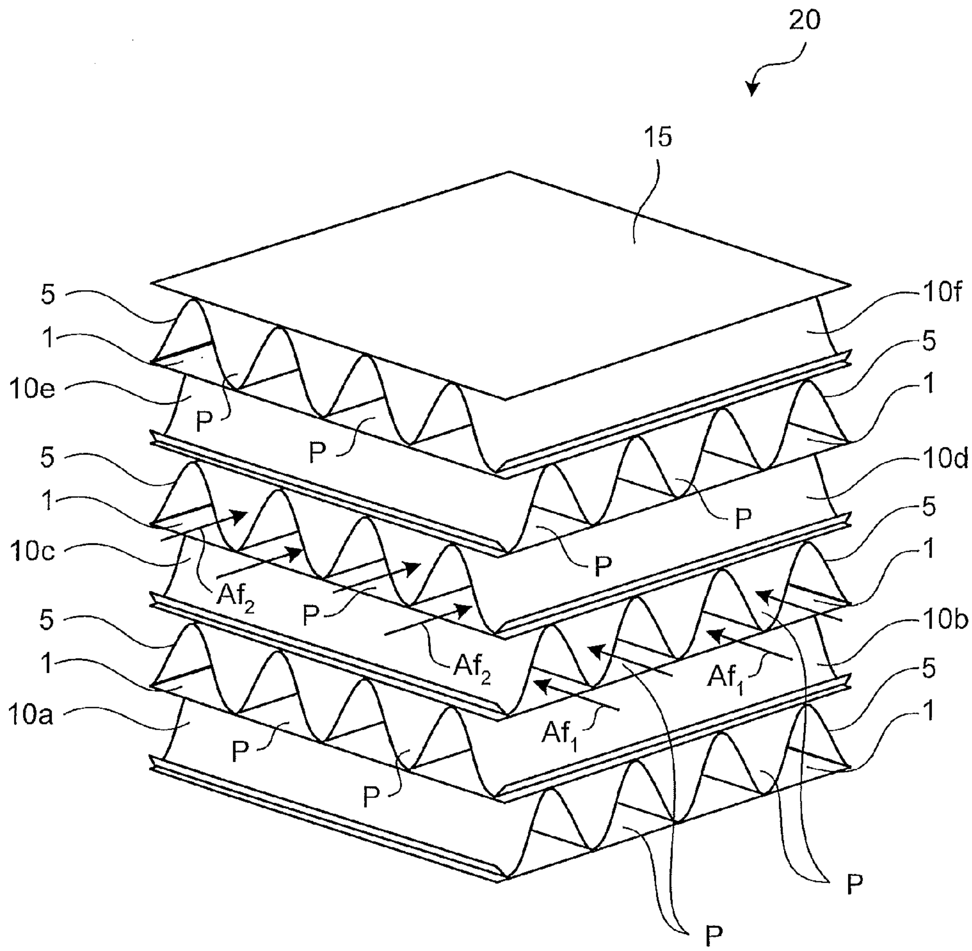

FIG.1

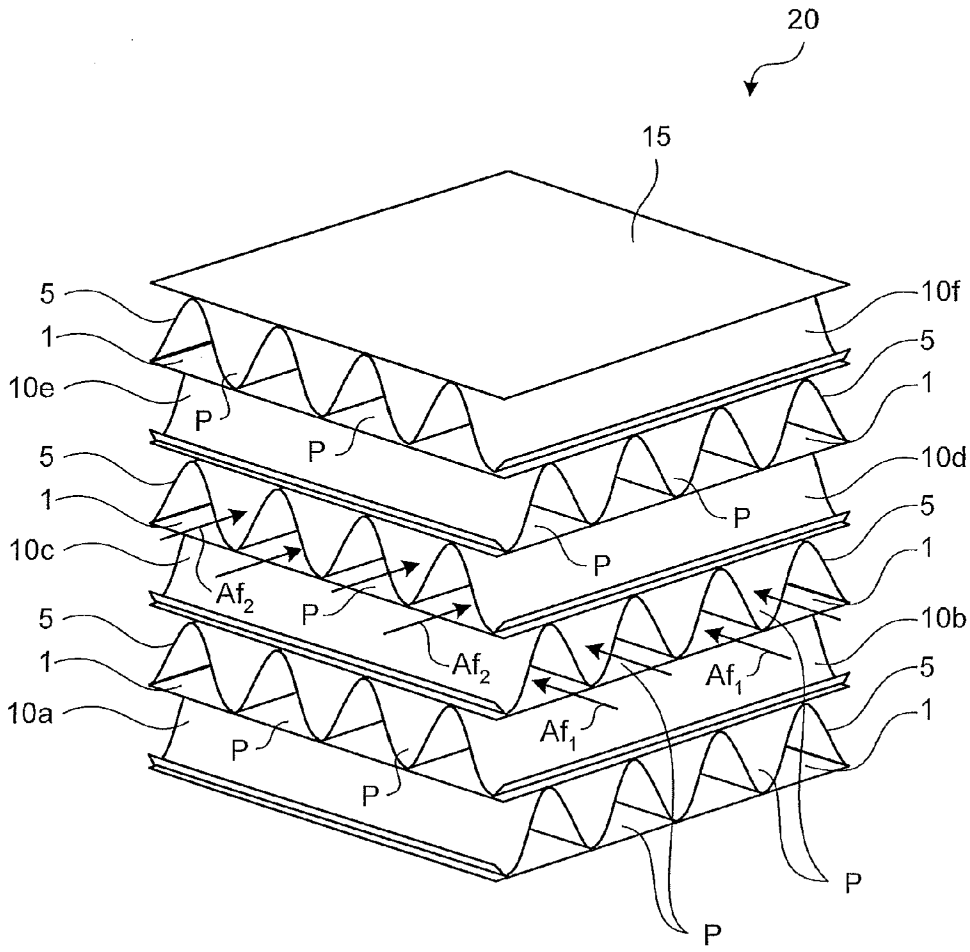
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FIG.2

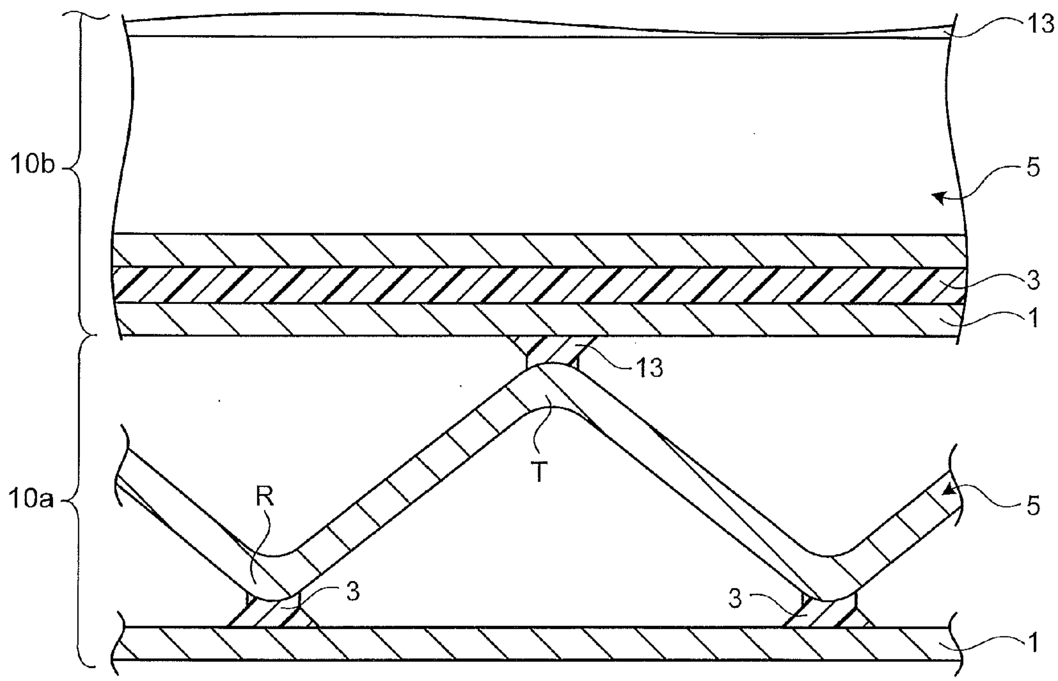

FIG.3

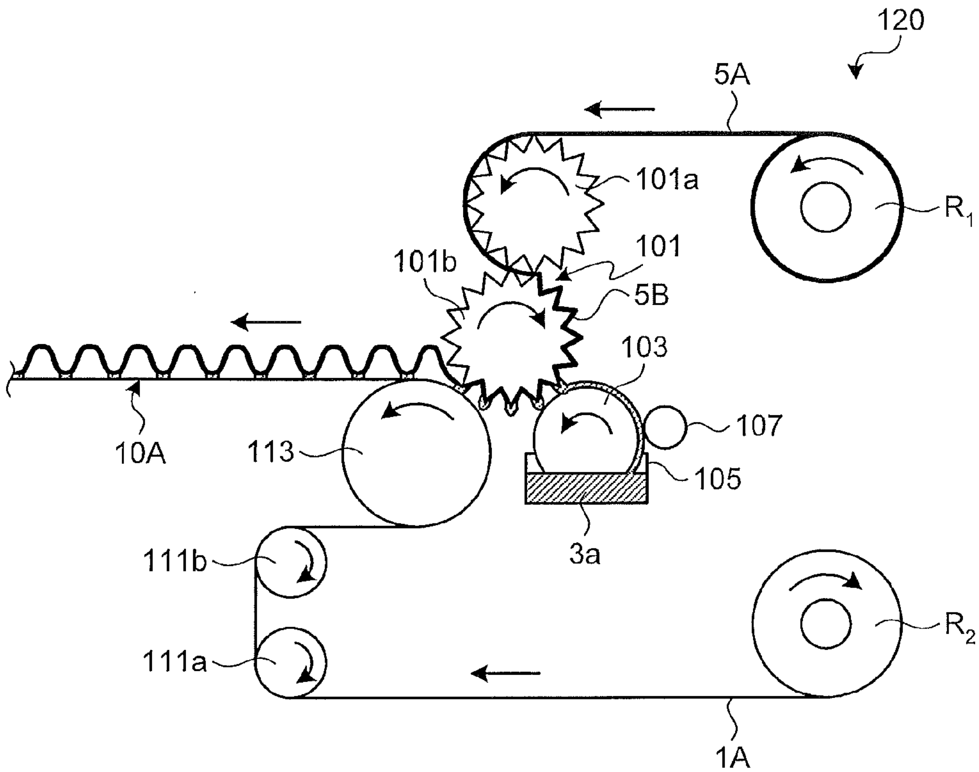

FIG.4

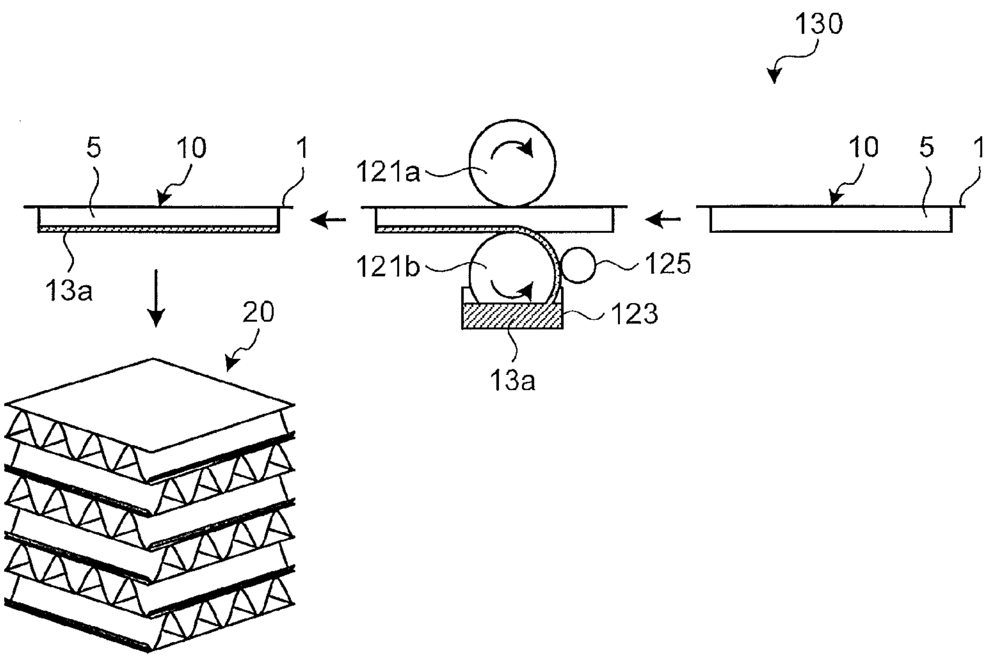

FIG.5

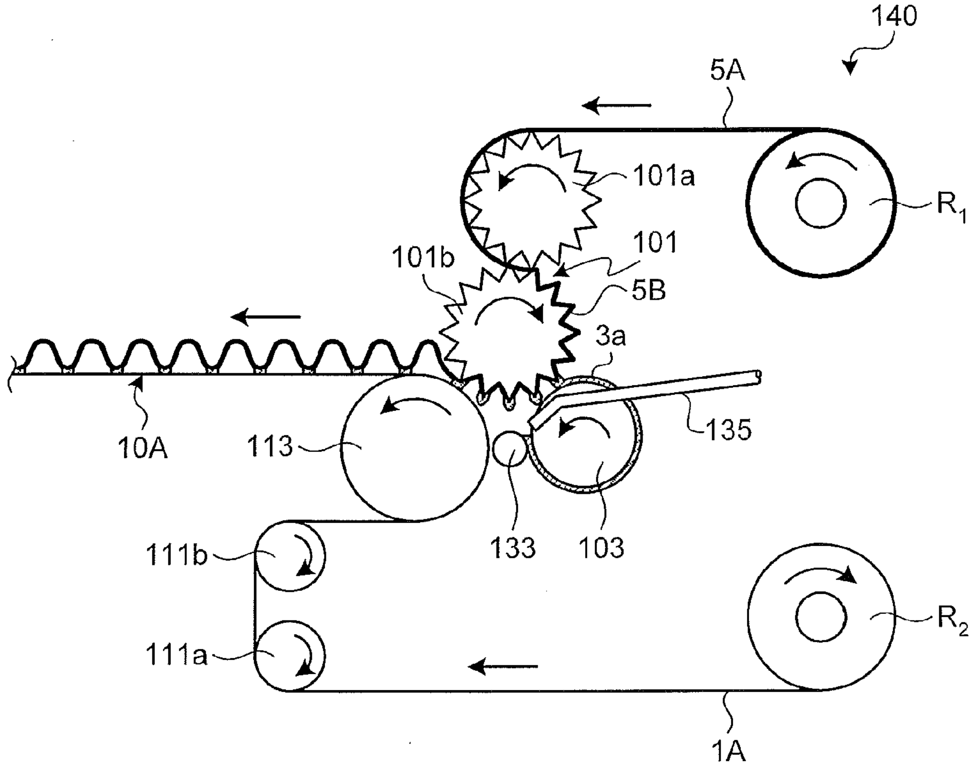

FIG.6

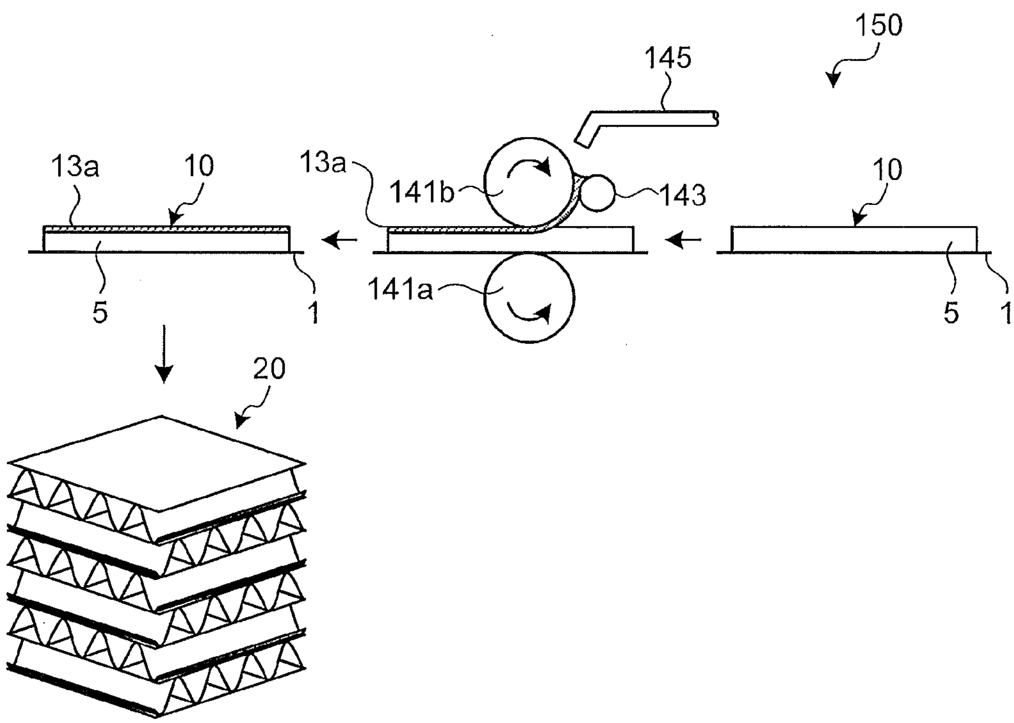

FIG.7

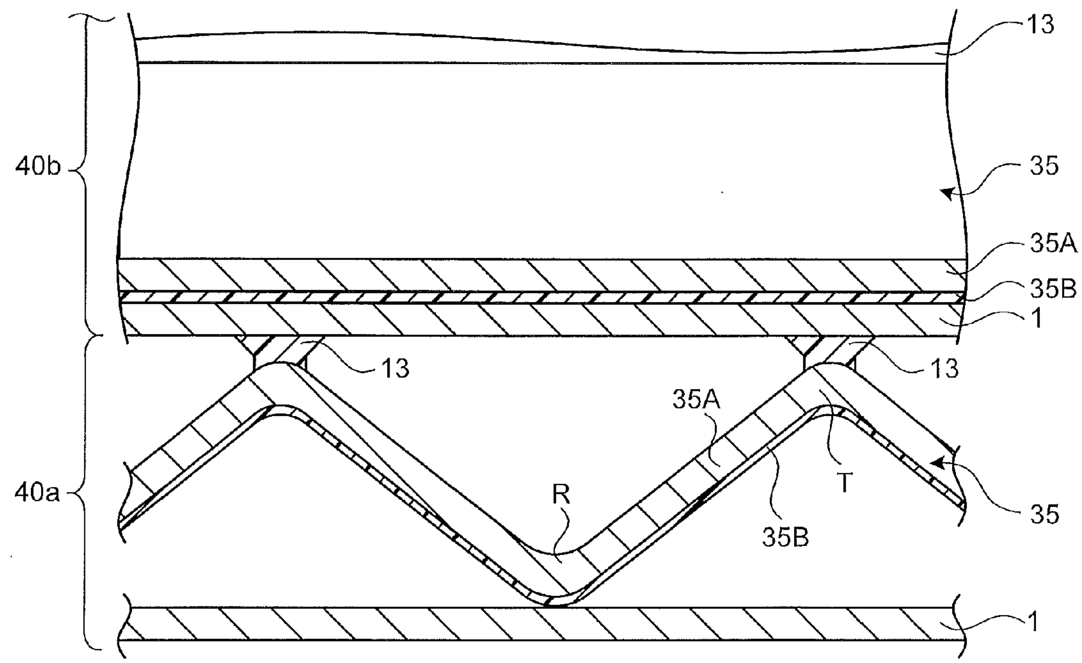

FIG.8

	EXAMPLE 1		EXAMPLE 2		COMPARATIVE EXAMPLE	
	IN HIGH-HUMIDITY ENVIRON-MENT	IN LOW-HUMIDITY ENVIRON-MENT	IN HIGH-HUMIDITY ENVIRON-MENT	IN LOW-HUMIDITY ENVIRON-MENT	IN HIGH-HUMIDITY ENVIRON-MENT	IN LOW-HUMIDITY ENVIRON-MENT
TEMPERATURE EXCHANGE EFFICIENCY (%)	70	70	70	70	69	70
MOISTURE EXCHANGE EFFICIENCY (%)	54	46	53	51	55	30
	0.85 *		0.96 *		0.55 *	
TOTAL HEAT EXCHANGE EFFICIENCY (%)	57	55	57	58	58	45

*: RATIO OF MOISTURE EXCHANGE EFFICIENCY IN LOW-HUMIDITY ENVIRONMENT TO MOISTURE EXCHANGE EFFICIENCY IN HIGH-HUMIDITY ENVIRONMENT

TOTAL HEAT EXCHANGE ELEMENT AND MANUFACTURING METHOD THEREOF

TECHNICAL FIELD

[0001] The present invention relates to a total heat exchange element and a manufacturing method thereof, the total heat exchange element being used in a heat exchanger included in an air-conditioning apparatus or a ventilator and being configured so as to exchange latent heat as well as to exchange sensible heat between two types of air flows. The present invention more specifically relates to a total heat exchange element used in a stationary-type heat exchanger and a manufacturing method thereof.

BACKGROUND ART

[0002] As for heat exchangers included in air-conditioning apparatuses and ventilators, there are two types such as rotation-type heat exchangers and stationary-type heat exchangers. In both types of heat exchangers, total heat exchange elements are preferably used because total heat exchange elements have higher heat exchange efficiency than sensible heat exchange elements, which exchange only sensible heat. In many situations, a total heat exchange element is obtained by manufacturing a long product by using a single-face corrugated cardboard manufacturing apparatus (i.e., single-facer apparatus) and using the long product as a material for the heat exchange element, the long product having a structure in which a sheet-like partition member and a corrugated-plate-like spacing member are pasted together.

[0003] A total heat exchange element used in a rotation-type heat exchanger is manufactured by applying an adhesive to a predetermined surface of the long product described above and rolling the long product into a wheel-like configuration. A total heat exchange element used in a stationary-type heat exchanger is manufactured by obtaining a plurality of element structuring units by cutting the long product described above into pieces of a predetermined size and stacking, in the manner of layers, the element structuring units oriented in predetermined directions (in other words, by stacking the element structuring units in the manner of layers in such a manner that the corrugation stripes of the spacing members included in the element structuring units that are positioned adjacent to each other in the layer stacking direction are substantially orthogonal to each other.) In this situation, the elements structuring units that are positioned adjacent to each other in the layer stacking direction are joined together by using an adhesive.

[0004] Between the total heat exchange elements that are used in rotation-type heat exchangers and the total heat exchange elements that are used in stationary-type heat exchangers, the functions that the partition members and the spacing members are expected to have are different, because operation principles of the heat exchangers are different. Roughly speaking, in the total heat exchange elements that are used in rotation-type heat exchangers, the partition members and the spacing members are expected to have heat storing and releasing properties as well as moisture storing and releasing properties. In contrast, in the total heat exchange elements that are used in stationary-type heat exchangers, because a latent heat exchanging process and a sensible heat exchanging process are performed between two types of air flows via the partition members, the partition members are expected to have heat conductivity and moisture permeability, whereas the spacing members are expected to play a role of securing air flow passages by maintaining intervals between the partition members and to have a certain degree of gas blocking properties for the purpose of inhibiting leaks of the air flows. The present invention relates to a total heat exchange element that is used in a stationary-type heat exchanger. Thus, in the following sections, a focus of the explanation will be placed on the total heat exchange elements that are used in stationary-type heat exchangers.

[0005] As materials for partition members and spacing members included in a total heat exchange element, paper, materials obtained by blending pulp and a resin and shaping the blended materials into a sheet-like form, resins, metallic foils, or the like are used. Usually, for the purpose of exchanging latent heat efficiently, a water-soluble or non-water-soluble moisture absorbent (moisture permeable agent) is added in advance to the material for the partition members. As the water-soluble moisture absorbent, for example, an alkali metal salt such as lithium chloride or an alkali earth metal salt such as calcium chloride may be used. As the non-water-soluble moisture absorbent, for example, silica gel or powder of a strongly acidic ion-exchange resin or a strongly basic ion-exchange resin may be used.

[0006] For example, Patent Document 1 describes a paper that can be used in a total heat exchange member. The paper is obtained by applying a moisture absorbing/releasing coating layer of which the main components are moisture absorbing/releasing powder (i.e., a non-water-soluble moisture absorbent) and a binder, onto one or both surfaces of a flame-retardant base paper, and further applying a thermal-adhesion-type adhesive layer onto one of the surfaces of the flame-retardant base paper. Also, Patent Document 2 describes an adsorbing sheet obtained by partially embedding granular adsorbing members into an adhesive layer formed on a base material for the sheet, and further covering the adhesive layer and the granular adsorbing members with an adsorbent layer containing a particulate adsorbent (i.e., a non-water-soluble moisture absorbent). Such an adsorbing sheet is used in, for example, a rotation-type total heat exchanger or a dehumidifying rotor.

[0007] Patent Document 3 describes a heat exchange element obtained by manufacturing a partition member (i.e., a flat plate) by using craft paper or a film having moisture permeability or moisture absorbing properties, and also, manufacturing a spacing member (i.e., a corrugated plate) by using a metallic foil on which a synthetic resin film is laminated or a synthetic resin film, and further adding a water-soluble moisture absorbent to the partition member. Patent Document 4 describes a composite heat-transfer element obtained by manufacturing a partition member (i.e., a liner) by using a paper to which a water-soluble moisture absorbent or non-water-soluble moisture absorbent has been added, and also, manufacturing a spacing member (i.e., a corrugated member) by using a metallic foil. The composite heat-transfer element can be used in a total heat exchanger.

[0008] Patent Document 5 describes a heat exchanger obtained by manufacturing a spacing member (i.e., a spacing plate) by using a material obtained by blending fiber (i.e., cellulose fiber) that has a high softening point with a resin that has a lower softening point than the fiber and making the blended material into the form of paper, and also, manufacturing an element structuring unit (i.e., a unit member) by joining, by way of thermal fusion bonding, the spacing member and a partition member together while using the same resin as a binder, and further stacking a predetermined number of element structuring units in the manner of layers by using an aqueous adhesive or by using the same resin as a binder.

[0009] Patent Document 6 describes a heat exchanger obtained by manufacturing a partition member by using a gas blocking product obtained by forming a moisture permeable film being capable of blocking air on one of the surfaces of a plate-like porous member, and also, forming a moisture absorbent layer on the other surface, and further joining the partition member and a spacing member together by using an aqueous adhesive.

[0010] Furthermore, Patent Document 7 describes a heat exchange element obtained by configuring a spacing member (i.e., a spacing plate) by disposing a thin film having air blocking properties so as to be in close contact with a porous member (i.e., woven cloth, nonwoven cloth, knitted cloth, paper, or the like), and also, manufacturing an element structuring unit (i.e., a unit member) by bonding the spacing member with a partition member (i.e., a partition plate) by using a thermal-adhesion-type adhesive layer formed on the entirety of one of the surfaces of the spacing member or the partition member, and subsequently stacking a predetermined number of element structuring units in the manner of layers by using an aqueous adhesive. The partition member included in the heat exchange element is configured by, for example, disposing a moisture permeable film so as to be in close contact with a porous member, the moisture permeable film being capable of selectively allow water vapor to permeate therethrough.

[0011] Patent Document 1: Japanese Patent Application Laid-open No. H10-153398

[0012] Patent Document 2: Japanese Patent Application Laid-open No. 2003-251133

[0013] Patent Document 3: Japanese Patent Application Laid-open No. H06-109395

[0014] Patent Document 4: Japanese Patent Application Laid-open No. H07-19789

[0015] Patent Document 5: Japanese Patent Application Laid-open No. H10-54691

[0016] Patent Document 6: Japanese Patent Application Laid-open No. 2001-27489

[0017] Patent Document 7: Japanese Patent Application Laid-open No. H08-219676

DISCLOSURE OF INVENTION

Problem to be Solved by the Invention

[0018] From the point of view of keeping manufacturing costs of total heat exchange elements down, it is more desirable to use a water-soluble moisture absorbent than to use a non-water-soluble moisture absorbent like in the paper that can be used in a total heat exchange member described in Patent Document 1 or in the adsorbing sheet described in Patent Document 2. For example, by applying an aqueous solution of a water-soluble moisture absorbent to a paper and drying the paper, it is possible to easily manufacture a material that is suitable for obtaining a partition member to which the moisture absorbent has been added.

[0019] It should be noted, however, that when having dissolved in water, many water-soluble moisture absorbents make the electric conductivity of the water (i.e., the aqueous solution) extremely high by causing ionization or the like. Thus, in air-conditioning apparatuses, ventilators, and the like including a total heat exchange element in which a water-soluble moisture absorbent has been added to the partition member, there is a possibility that the water-soluble moisture absorbent may dissolve into condensation water that can form during a heat exchanging process, and a serious malfunction like a tracking phenomenon may occur when the condensation water comes into contact with an electric power charging unit.

[0020] For the purpose of inhibiting such a malfunction, it is more desirable to configure a spacing member by using a material having water retention properties like paper than to configure a spacing member by using a metallic foil or a synthetic resin film like in the heat exchange element described in Patent Document 3 or in the composite heat-transfer element described in Patent Document 4, or than to configure a spacing member by using a material-blended paper containing a resin like in the heat exchanger described in Patent Document 5.

[0021] Further, like in the heat exchanger described in Patent Document 6, when a partition member and a spacing member are joined together by using an aqueous adhesive such as starch glue or a vinyl-acetate-based emulsion, although it is possible to enhance workability during the manufacturing process of the total heat exchange element and handleability of the adhesive, a phenomenon may occur in which the actual latent heat exchange efficiency level is lower than a latent heat exchange efficiency level estimated from a result of measuring the moisture permeability achieved by the partition member alone. Such a phenomenon does not occur in total heat exchange elements in which the partition member is manufactured by using a resin sheet or the like having low water retention properties. In other words, such a phenomenon is unique to total heat exchange elements in which the partition member is manufactured by using a water retentive material, like paper. This phenomenon occurs prominently in total heat exchange elements in which a large amount of water-soluble moisture absorbent has been added to the partition member.

[0022] During studies to determine the causes of the phenomenon described above, the inventors of the present invention have placed their focus on a situation in which, when a partition member to which a water-soluble moisture absorbent has been added and a spacing member manufactured by using a water retentive material are joined together by using an aqueous adhesive, between the time at which the aqueous adhesive is applied and the time at which the aqueous adhesive has dried and the joining process is completed, the water, which is the solvent in the aqueous adhesive, seeps into both the partition member and the spacing member, so that a part of the water-soluble moisture absorbent in the partition member moves into the spacing member via the aqueous adhesive. Because the water-soluble moisture absorbent moves from the partition member into the spacing member, when the partition member has been assembled into a total heat exchange element, the partition member is not able to maintain the moisture permeability that could be achieved when the partition member was by itself. It has been implied that, as a result, there is a possibility that the latent heat exchange efficiency may decrease.

[0023] For example, like in the heat exchanger described in Patent Document 7, in the case where an element structuring unit is manufactured by forming a thermal-adhesion-type adhesive layer on the entirety of one of the surfaces of the spacing member or the partition member and thermally bonding the spacing member or the partition member by using the adhesive layer, even if a water-soluble moisture absorbent has been added to the partition member, it is possible to prevent the water-soluble moisture absorbent from moving from the partition member into the spacing member. However, in the total heat exchanger described in Patent Document 7, the aqueous adhesive is used when the total heat exchange element is manufactured by stacking the predetermined number of element structuring units in the manner of layers. Thus, the water-soluble moisture absorbent moves from the partition member into the spacing member at that time. As a result, when the partition member has been assembled into the total heat exchange element, the partition member is not able to maintain the moisture permeability that could be achieved when the partition member was by itself. Consequently, the latent heat exchange efficiency decreases.

[0024] In view of the circumstances described above, it is an object of the present invention to obtain a total heat exchange element with which it is possible to easily constitute an air-conditioning apparatus or a ventilator that has high latent heat exchange efficiency and has high reliability. Further, it is another object of the present invention to obtain a manufacturing method of a total heat exchange element with which it is possible to easily constitute an air-conditioning apparatus or a ventilator that has high latent heat exchange efficiency and has high reliability.

Means for Solving Problem

[0025] A total heat exchange element according to the present invention has a stacked-layer structure in which sheet-like partition members added a water-soluble moisture absorbent thereto and spacing members are stacked alternately, the spacing members being joined with the partition members by using an adhesive so as to form air flow passages together with the partition members, wherein the spacing members have water retention properties, and the adhesive exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent.

[0026] A manufacturing method of a total heat exchange element according to the present invention having a stacked-layer structure in which sheet-like partition members added a water-soluble moisture absorbent thereto and spacing members are stacked alternately, the spacing members being joined with the partition members by using an adhesive so as to form air flow passages together with the partition members, the manufacturing method includes a unit manufacturing step of obtaining a plurality of element structuring units in each of which one of the partition members and a corresponding one of the spacing members each being made of a water retentive material are joined together by using the adhesive; and a layer stacking step of joining the element structuring units together by using an adhesive and obtaining the total heat exchange element in which the plurality of element structuring units are stacked in layers, wherein the adhesive used at the unit manufacturing step and the adhesive used at the layer stacking step each exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent.

EFFECT OF THE INVENTION

[0027] In the total heat exchange element according to the present invention, as the adhesive used for joining the partition members to which the water-soluble moisture absorbent has been added with the spacing members that have water retention properties, an adhesive that exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent is used. In other words, as the adhesive used for joining the partition members and the spacing members together, such an adhesive is used into which the water-soluble moisture absorbent is not able to dissolve, while the adhesive is in an unhardened state, and into which the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent is not able to seep, after the adhesive is hardened.

[0028] Thus, it is possible to inhibit the water-soluble moisture absorbent from moving from the partition members into the spacing members via the adhesive, during the manufacturing process of the total heat exchange element, needless to say, and also, even after the manufacturing process. As a result, in the total heat exchange element according to the present invention, it is easy to enhance the latent heat exchange efficiency by adding a desired amount of moisture absorbent to the partition members. In addition, it is also easy to inhibit the latent heat exchange efficiency from decreasing over the course of time.

[0029] Further, because the spacing members has water retention properties, even if condensation has occurred so that the water-soluble moisture absorbent dissolves into the condensation water, it is possible to have the condensation water absorbed by the spacing members. Thus, when an air-conditioning apparatus or a ventilator is structured by using the total heat exchange element according to the present invention, it is possible to inhibit serious malfunctions such as the tracking phenomenon that may occur when the condensation water in which the water-soluble moisture absorbent has dissolved comes into contact with an electric power charging unit of such an apparatus.

[0030] For these reasons, according to the present invention, it is easy to obtain a total heat exchange element with which it is possible to easily constitute an air-conditioning apparatus or a ventilator that has high latent heat exchange efficiency and has high reliability.

BRIEF DESCRIPTION OF DRAWINGS

[0031] FIG. **1** is a schematic perspective view illustrating an example of a total heat exchange element according to the present invention.

[0032] FIG. **2** is a schematic cross-sectional view illustrating a joint portion and the surroundings thereof between an element structuring unit and another element structuring unit positioned above the element structuring unit both of which are included in the total heat exchange element shown in FIG. **1**.

[0033] FIG. **3** is a schematic drawing illustrating an example of equipment that is used to manufacture a long element structuring unit member one after another at a unit manufacturing step included in a total heat exchange element manufacturing method according to the present invention.

[0034] FIG. **4** is a schematic drawing illustrating an example of equipment that is used to apply an adhesive to element structuring units at a layer stacking step included in the total heat exchange element manufacturing method according to the present invention.

[0035] FIG. **5** is a schematic drawing illustrating an example of equipment that is used to manufacture a long element structuring unit member one after another by using a hot-melt adhesive, at the unit manufacturing step included in the total heat exchange element manufacturing method according to the present invention.

[0036] FIG. **6** is a schematic drawing illustrating an example of equipment that is used to apply a hot-melt adhesive to element structuring units at the layer stacking step included in the total heat exchange element manufacturing method according to the present invention.

[0037] FIG. **7** is a schematic cross-sectional view illustrating a joint portion and the surroundings thereof between an element structuring unit and another element structuring unit that is positioned above the element structuring unit both of which are included in a total heat exchange element according to the present invention where a spacing member and a partition member are joined together by using a thermal-adhesion-type resin layer included in the spacing member as an adhesive.

[0038] FIG. **8** is a table illustrating results of measuring temperature exchange efficiency, moisture exchange efficiency, and total heat exchange efficiency in a high-humidity environment and in a low-humidity environment, for each of total heat exchange elements manufactured as Example 1, Example 2, and Comparative Example.

EXPLANATIONS OF LETTERS OR NUMERALS

[0039] **1** partition member
[0040] **3** adhesive
[0041] **5**, **35** spacing member
[0042] **10**, **10***a* to **10***f* element structuring unit
[0043] **13** adhesive
[0044] **20** total heat exchange element
[0045] **35**A base material for spacing members
[0046] **35**B thermal-adhesion-type resin layer

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0047] Exemplary embodiments of a total heat exchange element and a manufacturing method thereof according to the present invention will be explained in detail, with reference to the accompanying drawings. The present invention is not limited to the exemplary embodiments described below.

First Embodiment

[0048] FIG. **1** is a schematic perspective view illustrating an example of a total heat exchange element. A total heat exchange element **20** shown in FIG. **1** is of a cross-flow type and has a stacked-layer structure in which sheet-like partition members **1** and corrugated-plate-like spacing members **5** are stacked in the manner of layers so as to alternate. In the total heat exchange element **20**, the stacked-layer structure is formed by stacking six element structuring units **10***a* to **10***f* in the manner of layers. A top plate member **15** is further stacked on top of the element structuring unit **10***f* that is provided in the uppermost position. The corrugation stripes of the spacing member **5** in any one of the element structuring units are substantially orthogonal, in a planar view, to the corrugation stripes of the spacing member **5** in another one of the element structuring units that is positioned above or below the one of the element structuring units. In other words, the lengthwise directions of ridges or grooves of the corrugated-plate-like spacing member **5** in any one of the element structuring units are substantially orthogonal, in a planar view, to the lengthwise directions of ridges or grooves of the corrugated-plate-like spacing member **5** in another one of the element structuring units that is positioned above or below the one of the element structuring units.

[0049] Each of the partition members **1** includes a base material and a water-soluble moisture absorbent that has been added to the base material. As the base material for each of the partition members **1**, such a material is used to which it is possible to add a water-soluble moisture absorbent and with which it is possible to join a corresponding one of the spacing members **5** by using an adhesive described below. From the point of view of inhibiting gas from being exchanged between two types of air flows between which a heat exchanging process is to be performed, it is more desirable to use, as the base material, a material having a high level of air permeation resistance (e.g., approximately 200 seconds or higher) than to use a material having a low level of air permeation resistance (Hereinafter, the levels of air permeation resistance denote ones measured by using a Gurley tester). In the case where a material having a low level of air permeation resistance is used, it is desirable to impregnate the base material having the low level of air permeation resistance with a water-soluble polymer such as polyvinyl alcohol as a sealing agent. In the case where a paper that is designed so as to achieve a high level of air permeation resistance through, for example, a process of crushing cellulose fiber (pulp) is used as the base material, it is possible to obtain the partition members **1** that are able to achieve ideal performance only by impregnating the base material with a water-soluble moisture absorbent.

[0050] As the water-soluble moisture absorbent described above, it is possible to use, for example, an alkali metal salt that is deliquescent such as lithium chloride, an alkali earth metal salt that is deliquescent such as calcium chloride, alginic acid, a salt of alginic acid, a polysaccharide such as carrageenan or chitosan, or urea. It is also acceptable to use any other substances having water solubility and moisture absorbing properties as the water-soluble moisture absorbent. Deliquescent alkali metal salts and deliquescent alkali earth metal salts have higher capabilities of adsorbing water than other water-soluble moisture absorbents and are able to dramatically change the performance level of the total heat exchange element **20** according to an added amount thereof. Thus, a deliquescent alkali metal salt or a deliquescent alkali earth metal salt is particularly desirable as the water-soluble moisture absorbent.

[0051] It is possible to add the water-soluble moisture absorbent to the base material by, for example, preparing an aqueous solution of the water-soluble moisture absorbent and impregnating the base material with the aqueous solution or by applying the aqueous solution to one or both surfaces of the base material by using equipment such as a gravure coater. Further, it is acceptable to add, as necessary, a binder component or a sealing agent to the aqueous solution. It should be noted, however, that the binder component may inhibit the base material from being impregnated with the water-soluble moisture absorbent, depending on what type of binder component is used. Thus, in the case where a binder component is added to the aqueous solution, it is desirable to carefully select the type of binder component and the added amount thereof.

[0052] Although the desirable thickness of each of the partition members **1** depends on the level of moisture permeability that the partition members **1** are expected to have and the material strength of the base material, it is generally desirable to configure the thickness of each of the partition members **1**

so as to be approximately 20 μm to 100 μm, because when the partition members **1** are too thick, the moisture permeability of the partition members **1** decreases, whereas when the partition members **1** are too thin, the partition members **1** may be damaged during the manufacturing process of the element structuring units or the total heat exchange element due to an imbalance in the strength between the partition members **1** and the spacing members **5** or due to too low a material strength of the partition members **1**. It is possible to manufacture the top plate member **15** by using the same material as the base material for the partition members **1**.

[0053] The spacing members **5** have water retention properties, and a material having water retention properties (hereinafter, a "water retentive material") is used as a material for the spacing members **5**. Examples of the water retentive material include materials obtained by impregnating paper, woven cloth, or nonwoven cloth made of cellulose fiber with a water-absorbing resin or by applying a water-absorbing resin to the same. As a material for the spacing members **5**, it is also possible to use a material obtained by impregnating woven cloth or nonwoven cloth made of synthetic fiber having no water retention properties with a water-absorbing resin or by applying a water-absorbing resin to the same, or a material-blended paper made of cellulose fiber and a resin, because these materials also have water retention properties, although only slight. It should be noted, however, that the water retention amounts of the spacing members **5** become smaller when any of these materials is used.

[0054] From the point of view of ensuring the water retention properties of the spacing members **5** and the strength of the total heat exchange element **20** as a whole, it is desirable to configure each of the spacing members **5** so as to be thick. However, if the spacing members **5** alone are configured to be too thick, a problem will arise where the strengths of the spacing members **5** and the partition members **1** become imbalanced, so that deformation may occur during the manufacturing process of the element structuring units or the total heat exchange element. In addition, in case of fire, it is not desirable to have a large amount of burnable substances. Further, configuring the spacing members **5** so as to be thick can be a cause of an increase in the costs. Thus, it is generally desirable to configure the thickness of each of the spacing members **5** so as to be approximately 50 μm to 250 μm.

[0055] Further, it is also acceptable to add, in advance, a flame retardant to each of the spacing members **5**, as long as the water retention properties thereof are not inhibited. Examples of the flame retardant include materials that are often used in the process of arranging papers to be flame retardant, fire-proof or the like, such as guanidine salts e.g., guanidine hydrochloride, guanidine sulfate, guanidine sulfamate, and inorganic salts e.g., ammonium sulfamate, ammonium phosphate, ammonium sulfate, calcium chloride, and magnesium chloride.

[0056] Each of the element structuring units is formed by joining one partition member **1** and one spacing member **5** by using an adhesive. The element structuring units that are positioned adjacent to each other in the layer stacking direction as well as the element structuring unit **10***f* provided in the uppermost position and the top plate member **15** are also joined together by an adhesive. Because each of the partition members **1** is a sheet-like member and each of the spacing members **5** is a corrugated-plate-like member, air flow passages Ps are formed in the space between the partition member **1** and the spacing member **5** in each of the element structuring units **10***a* to **10***f*, the space between the spacing member **5** included in any one of the element structuring units **10***a* to **10***e* and the partition member **1** included in the one of the element structuring units **10***b* to **10***f* that is positioned above the element structuring unit, and the space between the spacing member **5** included in the element structuring unit **10***f* and the top plate member **15**.

[0057] The total heat exchange element **20** performs a latent heat exchanging process and a sensible heat exchanging process via the partition members **1**, between air flows flowing in the air flow passages P formed below the partition members **1** and air flows flowing in the air flow passages P formed above the partition members **1**. For example, of the two types of air flows between which the heat exchanging processes are performed, one is an airflow (i.e., a primary air flow) that is taken into the inside of a building from the outside of the building, whereas the other is an airflow (i.e., a secondary air flow) that is discharged to the outside of the building from the inside of the building. In the example shown in FIG. **1**, air flows Af_1 and other air flows Af_2 between which the heat exchanging processes are performed via the partition member **1** included in the element structuring unit **10***d* are indicated with arrows drawn with solid lines.

[0058] The total heat exchange element **20** that is configured as described above is characterized with the adhesive described above that is used for joining the partition members **1** and the spacing members **5** together. Thus, in the following sections, the adhesive will be explained in detail, with reference to FIG. **2**.

[0059] FIG. **2** is a schematic cross-sectional view illustrating a joint portion and the surroundings thereof between the element structuring unit **10***a* and the element structuring unit **10***b* that is positioned above the element structuring unit **10***a* both of which are included in the total heat exchange element **20** described above. As shown in FIG. **2**, in each of the element structuring units **10***a* and **10***b*, the partition member **1** and the spacing member **5** are joined together by adhesive **3** that is applied to the rear surface side of a corrugated groove portion R of the spacing member **5**. The element structuring unit **10***a* and the element structuring unit **10***b* are joined together by adhesive **13** that is applied to the upper surface side of a corrugated ridge portion T of the spacing member **5** included in the element structuring unit **10***a*. Also, the partition member **1** and the spacing member **5** in each of the other element structuring units **10***c* to **10***f* shown in FIG. **1**; any two of the other element structuring units **10***c* to **10***f* that are positioned adjacent to each other in the layer stacking direction; and the element structuring unit **10***f* and the top plate member **15** are joined together in the same manner as described above.

[0060] The adhesive **3** and the adhesive **13** exhibits insolubility to the water-soluble moisture absorbent that has been added to the partition members **1** or an aqueous solution of the water-soluble moisture absorbent. In other words, while the adhesive is in an unhardened state, the water-soluble moisture absorbent with which the partition members **1** are impregnated is not able to dissolve into the adhesive. Also, after the adhesive is hardened, the water-soluble moisture absorbent and an aqueous solution of the water-soluble moisture absorbent are not able to seep into the adhesive. Specific examples of the adhesive include organic-solvent-based adhesives (including non-aqueous emulsion-type adhesives) that do not contain water as a solvent, solventless reactive adhesives, and hot-melt adhesives.

[0061] In the total heat exchange element **20** in which the partition members **1** and the spacing members **5** are joined together by the adhesive **3** and the adhesive **13**, it is possible to inhibit the water-soluble moisture absorbent from moving into the spacing members **5** from the partition members **1** via the adhesive **3** and/or the adhesive **13**, during the manufacturing process thereof, needless to say, and also, even after the manufacturing process. The water-soluble moisture absorbent is not contained in the adhesive **3** and the adhesive **13**. Further, due to some water that has been adsorbed by the adhesive **3** and/or the adhesive **13** from the air during the manufacturing process, during a storing process, or in actual use thereof, the adhesive **3** and/or the adhesive **13** may allow a very small amount of the water-soluble moisture adsorbent to dissolve into the adhesive or may allow a very small amount of the water-soluble moisture adsorbent to seep into the adhesive. In the present description, the "unhardened state" of a hot-melt adhesive denotes a state in which the hot-melt adhesive is softened or melted.

[0062] In the total heat exchange element **20** configured as described above, the partition members **1** and the spacing members **5** are joined together by using the adhesive **3** and the adhesive **13**. Thus, it is easy to enhance the latent heat exchange efficiency by adding a desired amount of moisture absorbent to the partition members **1**. It is also easy to inhibit the latent heat exchange efficiency from decreasing over the course of time. In addition, because it is possible to inhibit the moisture absorbent from moving from the partition members **1** into the spacing members **5**, it is possible to reduce the amount of water-soluble moisture absorbent that is required to obtain a total heat exchange element having a level of latent heat exchange efficiency that is the same as or similar to that of a conventional total heat exchange element. As a result, it is also easy to reduce the costs.

[0063] Further, because it is possible to inhibit the moisture absorbent from moving from the partition members **1** into the spacing members **5**, it is also possible to inhibit deformation of the element structuring units caused by the spacing members **5** absorbing moisture and becoming soft or the partition members **1** and the spacing members **5** absorbing moisture and expanding/shrinking or the strengths thereof changing, during the manufacturing process of the total heat exchange element **20**. As a result, it is possible to have excellent workability during the manufacturing process of the element structuring units, excellent handleability of the element structuring units, and excellent workability and productivity during the manufacturing process of the total heat exchange element **20**.

[0064] In addition, because the spacing members **5** have water retention properties, even if condensation has occurred in the total heat exchange element **20** so that the water-soluble moisture absorbent dissolves into the condensation water, it is possible to have the condensation water absorbed by the spacing members. Thus, in an apparatus such as an air-conditioning apparatus or a ventilator that is structured by using the total heat exchange element **20**, it is possible to inhibit serious malfunctions such as the tracking phenomenon that may occur when the condensation water in which the water-soluble moisture absorbent has dissolved comes into contact with an electric power charging unit of such an apparatus.

[0065] For the reasons stated above, with the configuration of the total heat exchange element **20**, is easy to obtain a total heat exchange element having high latent heat exchange efficiency. Further, it is also easy to constitute an air-conditioning apparatus, a ventilator, or the like that has high reliability by using the total heat exchange element **20**. In the case where the total heat exchange element **20** is used in an apparatus that is installed indoor like an air-conditioning apparatus or a ventilator, it is desirable to use a solventless reactive adhesive or a hot-melt adhesive as the adhesive **3** and the adhesive **13** so that no organic solvent is emitted therefrom and no odor is released therefrom. In the case where a hot-melt adhesive is used, the process of joining the partition members **1** and the spaces **5** together is completed when the hot-melt adhesive that has been melt becomes hard through natural cooling or through a chemical reaction process. Thus, there is no need to perform a drying step. As a result, it is easy to reduce the time required to manufacture the total heat exchange element **20** and to reduce the input energy required to manufacture the total heat exchange element **20**. Consequently, it is easy to reduce the costs and to reduce environmental burdens on the surrounding environment.

[0066] It is possible to manufacture the total heat exchange element **20** that is able to achieve the technical advantageous effects as described above by using a method that includes, for example, a unit manufacturing step of obtaining a plurality of element structuring units in each of which a partition member is joined with a spacing member having water retention properties by using an adhesive; and a layer stacking step of joining the element structuring units together by using an adhesive and obtaining the total heat exchange element in which the plurality of element structuring units are stacked in the manner of layers. In this situation, at the unit manufacturing step and at the layer stacking step, an adhesive exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent is used. In other words, such an adhesive is used into which the water-soluble moisture absorbent is not able to dissolve, while the adhesive is in an unhardened state, and into which the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent is not able to seep, after the adhesive is hardened. In the following sections, each of the steps included in this method will be explained in detail.

[0067] For example, it is possible to divide the unit manufacturing step into a first sub-step and a second sub-step. At the first sub-step, first, a long material used for making the spacing members **5** (cf. FIG. **1**) having water retention properties is shaped into a corrugated-plate form so as to obtain a long corrugated-plate-like product. After that, the adhesive **3** (cf. FIG. **2**) in an unhardened state is applied to apex portions of the corrugated ridges on one side of the corrugated-plate-like product. After that, a long material (to which the water-soluble moisture absorbent has been added) used for making the partition members **1** (cf. FIG. **1**) is disposed so as to abut against the corrugated-plate-like product. Subsequently, the unhardened adhesive is hardened so that a long element structuring unit member is obtained by joining the long material used for making the partition members **1** with the corrugated-plate-like product.

[0068] At the second sub-step, the long element structuring unit member that has been obtained at the first sub-step is cut into pieces of a predetermined size, so as to obtain the plurality of element structuring units in each of which a partition member **1** and the spacing member **5** are joined together by the adhesive **3**. The obtained element structuring units correspond to the element structuring units **10**_a_ to **10**_f_ shown in FIG. **1**.

[0069] At the layer stacking step that is performed after the unit manufacturing step, first, the adhesive **13** (cf. FIG. **2**) in an unhardened state is applied to apex portions of the corrugated ridges of the spacing members **5** included in the element structuring units. Subsequently, the element structuring units to which the unhardened adhesive (i.e., the adhesive **13** in an unhardened state) has been applied are sequentially stacked in the manner of layers, while determining the orientation of each of the element structuring units in such a manner that the corrugation stripes of the spacing member **5** in any one of the element structuring units are substantially orthogonal, in a planar view, to the corrugation stripes of the spacing member **5** in another one of the element structuring units that is positioned above or below the one of the element structuring units. After that, the top plate member **15** (cf. FIG. **1**) is stacked on top of the uppermost element structuring unit. Subsequently, by hardening the adhesive that has been in the unhardened state, the element structuring units that are positioned adjacent to each other in the layer stacking direction as well as the uppermost element structuring unit and the top plate member **15** are joined together so that the total heat exchange element **20** shown in FIG. **1** is obtained.

[0070] At the unit manufacturing step described above, it is possible to manufacture the long element structuring unit member one after another, by using, for example, equipment as shown in FIG. **3**. In this situation, the long material used for making the spacing members and the long material used for making the partition members are shaped in rolls in advance, respectively.

[0071] FIG. **3** is a schematic drawing illustrating an example of the equipment that is used to manufacture the long element structuring unit member one after another at the unit manufacturing step described above. Equipment **120** shown in FIG. **3** is a single-facer apparatus. The single-facer apparatus shapes a long material **5**A used for making the spacing members **5** into a roll R_1 in advance, and also shapes a long material **1**A used for making the partition members **1** (cf. FIG. **1**) into a roll R_2 in advance.

[0072] The material **5**A that is pulled out of the roll R_1 in the equipment **120** is first forwarded to a corrugator **101** including a pair of corrugating rollers **101***a* and **101***b*. The corrugator **101** is configured so that the upper corrugating roller **101***a* in the form of a gear and the lower corrugating roller **101***b* also in the form of a gear rotate while being engaged with each other. The material **5**A is continuously shaped into the corrugated-plate form at the position where the corrugating roller **101***a* and the corrugating roller **101***b* are engaged with each other. As a result, a long corrugated-plate-like product **5**B is manufactured one after another.

[0073] After that, the corrugated-plate-like product **5**B is forwarded in a predetermined direction by the lower corrugating roller **101***b*, and an adhesive **3***a* in an unhardened state is applied to the corrugated-plate-like product **5**B by an application roller **103** while the corrugated-plate-like product **5**B is being forwarded. The adhesive **3***a* in the unhardened state is stored in an adhesive tank **105**, while the circumferential surface of the application roller **103** is partially immersed in the adhesive tank **105**. Also, the circumferential surface of the application roller **103** is substantially in contact with apex portions of gear teeth of the lower corrugating roller **101***b*.

[0074] When the application roller **103** rotates in a predetermined direction, the adhesive **3***a* in the unhardened state adheres to the circumferential surface of the application roller **103**, so that the adhesive **3***a* is further applied to the one side of the corrugated-plate-like product **5**B. To avoid a situation in which an excessive amount of the adhesive **3***a* in the unhardened state adheres to the circumferential surface of the application roller **103**, a squeezing roller **107** is disposed near the application roller **103**. By adjusting the gap between the lower corrugating roller **101***b* and the squeezing roller **107**, it is possible to adjust the amount of the adhesive **3***a* in the unhardened state to be applied to the corrugated-plate-like product **5**B. In the case where a hot-melt adhesive is used as the adhesive **3** (cf. FIG. **2**), the adhesive tank **105** is provided with, for example, a heater (not shown), so that the hot-melt adhesive is melted by the heater, and the adhesive **3***a* in the unhardened state can be obtained.

[0075] The material **1**A that is pulled out of the roll R_2 is introduced to a press roller **113** by two guide rollers **111***a* and **111***b*. The press roller **113** is disposed so that the circumferential surface thereof is substantially in contact with apex portions of gear teeth of the lower corrugating roller **101***b*. During the process in which the press roller **113** forwards the material **1**A in a predetermined direction, the material **1**A is pressed so as to be in contact with the corrugated-plate-like product **5**B.

[0076] Because the adhesive **3***a* in the unhardened state has been applied to the corrugated-plate-like product **5**B as described above, the adhesive **3***a* in the unhardened state is hardened by using a predetermined means (not shown; e.g., a heater, an artificial light source that emits light in a predetermined wavelength range, an air blower that blows out warm air, or an air blower that blows out cold air) after the material **1**A is pressed so as to be in contact with the corrugated-plate-like product **5**B, so that the corrugated-plate-like product **5**B and the material **1**A are joined together by the hardened adhesive **3** (cf. FIG. **2**). As a result, a long element structuring unit member **10**A used for making the element structuring units is manufactured one after another. The corrugating rollers **101***a* and **101***b* and the press roller **113** are heated to a predetermined temperature of, for example, approximately 150° C. or higher so that it is easy to adjust the shape of the corrugated-plate-like product **5**B. In FIG. **3**, the rotation directions of the rollers and the transport directions of the materials **1**A and **5**A are indicated with arrows drawn with solid lines.

[0077] After that, by cutting the element structuring unit member **10**A into pieces of the predetermined size, one by one, starting from an end of the element structuring unit member **10**A while using a cutting machine, the element structuring units serving as the element structuring units **10***a* to **10***f* (cf. FIG. **1**) are manufactured one after another.

[0078] At the layer stacking step that is performed to obtain the total heat exchange element by stacking, in the manner of layers, the plurality of element structuring units that have been manufactured in this manner, it is possible to apply the adhesive to the element structuring units by using, for example, equipment of which a schematic drawing is shown in FIG. **4**.

[0079] Equipment **130** shown in FIG. **4** includes a pair of rollers **121***a* and **121***b*, an adhesive tank **123** in which an adhesive **13***a* in an unhardened state is stored, a squeezing roller **125** that is disposed near the roller **121***b*, and a transporting device (not shown). Each of the element structuring units **10** is transported to the pair of rollers **121***a* and **121***b* by the transporting device, while being positioned in such a manner that the partition member **1** is on top, while the spacing member **5** is on the bottom. The adhesive **13***a* in the unhardened state is applied to each of the element structuring units **10** at the pair of rollers **121***a* and **121***b*. The plurality of element structuring units **10** are transported to the pair of rollers **121***a* and **121***b* at predetermined intervals.

[0080] Of the pair of rollers **121***a* and **121***b*, the roller **121***a* on the upper side functions as a transporting roller that transports each of the element structuring units **10** in the predetermined direction. A roller **120***b* on the lower side is partially immersed in the adhesive tank **123** and functions as an application roller for applying the adhesive **13***a* in the unhardened state to each of the element structuring units **10**. When the roller **121***b* rotates in the predetermined direction, the adhesive **13***a* in the unhardened state adheres to the circumferential surface of the roller **121***b*, so that the adhesive **13***a* is further applied to the spacing member **5** included in each of the element structuring units **10**. The squeezing roller **125** is disposed near the roller **121***b* and removes excessive adhesive **13***a* in the unhardened state that has been adhered to the circumferential surface of the roller **121***b*. By adjusting the gap between the roller **121***b* and the squeezing roller **125**, it is possible to adjust the amount of the adhesive **13***a* in the unhardened state to be applied to each of the element structuring units **10**. In the case where a hot-melt adhesive is used as the adhesive **13** (cf. FIG. **2**), the adhesive tank **123** is provided with, for example, a heater (not shown), so that the hot-melt adhesive is melted by the heater, and the adhesive **13***a* in the unhardened state can be obtained.

[0081] The element structuring units **10** to which the adhesive **13***a* in the unhardened state has been applied by the equipment **130** are stacked in the manner of layers while being oriented in the predetermined directions, as explained above, and further, the top plate member **15** (cf. FIG. **1**) is stacked on top of the uppermost element structuring unit. After that, a process of hardening the adhesive **13***a* that has been in the unhardened state is performed by using a predetermined means (not shown; e.g., a heater, an artificial light source that emits light in a predetermined wavelength range, an air blower that blows out warm air, or an air blower that blows out cold air). When this hardening process has been completed, the total heat exchange element **20** (cf. FIGS. **1** and **4**) in which the element structuring units **10** that are positioned adjacent to each other in the layer stacking direction are joined together by the adhesive **13** (cf. FIG. **2**) is obtained.

[0082] In the case where a hot-melt adhesive is used at the unit manufacturing step, it is also possible to manufacture the element structuring unit member **10**A by using equipment **140** of which a schematic drawing is shown in FIG. **5**. Instead of an adhesive tank **105** and the squeezing roller **107** shown in FIG. **3**, the equipment **140** shown in FIG. **5** includes: a feed roller **133** that is disposed so as to be in contact with the circumferential surface of the application roller **103** and supplies the adhesive **3***a* in the unhardened state (i.e., the hot-melt adhesive that has been melted) to the circumferential surface of the application roller **103**; a supply pipe **135** that supplies the melted hot-melt adhesive to an area in which the application roller **103** and the feed roller **133** rub against each other while being in contact with each other, from above the area; and an adhesive supply source (not shown) that sends the melted hot-melt adhesive into the supply pipe **135**. Except for these features, the configuration of the equipment **140** is the same as the configuration of the equipment **120** shown in FIG. **3**. Thus, some of the constituent elements shown in FIG. **5** that are the same as the constituent elements shown in FIG. **3** are referred to by using the same reference characters as in FIG. **3**, and the explanation thereof will be omitted.

[0083] Further, in the case where a hot-melt adhesive is used at the layer stacking step, it is also possible to apply the adhesive **13***a* in the unhardened state (i.e., the hot-melt adhesive that has been melted) to the element structuring units **10** by using equipment **150** of which a schematic drawing is shown in FIG. **6**. The equipment **150** shown in FIG. **6** includes: a pair of rollers **141***a* and **141***b*; a feed roller **143** that is disposed near the roller **141***b* and supplies the adhesive **13***a* in the unhardened state to the circumferential surface of the roller **141***b*; a supply pipe **145** that supplies the melted hot-melt adhesive to a border area between the roller **141***b* and the feed roller **143**, from above the border area; an adhesive supply source (not shown) that sends the melted hot-melt adhesive into the supply pipe **145**; and a transporting device (not shown).

[0084] Of the pair of rollers **141***a* and **141***b*, the roller **141***a* on the lower side functions as a transporting roller that transports each of the element structuring units **10** in the predetermined direction. The roller **141***b* on the upper side functions as an application roller for applying the adhesive **13***a* in the unhardened state to each of the element structuring units **10**. Each of the element structuring units **10** is transported to the pair of rollers **141***a* and **141***b* by the transporting device, while being positioned in such a manner that the partition member **1** is on the bottom, while the spacing member **5** is on top. The adhesive **13***a* in the unhardened state is applied to each of the element structuring units **10** at the pair of rollers **141***a* and **141***b*.

Second Embodiment

[0085] It is also possible to join the partition member and the spacing member together that are included in each of the element structuring units structuring a total heat exchange element and to join the element structuring units together, by configuring the spacing member by using a base material and a thermal-adhesion-type resin layer and using the thermal-adhesion-type resin layer included in the spacing member as an adhesive. The overall shape of the total heat exchange element in which such a joining mode is used can be the same as, for example, the overall shape of the total heat exchange element **20** shown in FIG. **1**. Thus, the drawing of the total heat exchange element is omitted.

[0086] FIG. **7** is a schematic cross-sectional view illustrating a joint portion and the surroundings thereof between an element structuring unit and another element structuring unit that is positioned above the element structuring unit both of which are included in an example of the total heat exchange element where the joining mode described above is used. In FIG. **7**, an element structuring unit **40***a* and another element structuring unit **40***b* that is positioned above and joined with the element structuring unit **40***a* are shown. Some of the constituent elements shown in FIG. **7** that are the same as the constituent elements shown in FIG. **2** are referred to by using the same reference characters as in FIG. **2**, and the explanation thereof will be omitted.

[0087] Each of the element structuring units **40***a* and **40***b* includes the partition member **1** and a spacing member **35** that is joined with the partition member **1**. Each of the spacing members **35** includes: a base material **35**A that is manufactured by using a water retentive material; and a thermal-adhesion-type resin layer **35**B that is provided on the entirety of a lower surface of the base material **35**A. The thermal-adhesion-type resin layer **35**B is formed by, for example, attaching a film or a sheet made of a thermal-adhesion-type resin such as polyethylene or ethylene-vinyl acetate copolymer (EVA), onto the one of the surfaces of the base material **35**A by way of thermal fusion bonding. The sheet or the film may be porous or may not be porous. In the case where the thermal-adhesion-type resin layer **35**B is formed by using a porous film or a porous sheet, it is easy to enhance the water retention properties of the spacing member **35**. In contrast, in the case where the thermal-adhesion-type resin layer **35**B is formed by using a non-porous film or a non-porous sheet, it is easy to enhance the level of air permeation resistance of the spacing member **35**.

[0088] The partition member **1** and the spacing member **35** included in each of the element structuring units **40***a* and **40***b* are joined together on the rear surface side of the corrugated groove portion R of the spacing member **35**, by using the thermal-adhesion-type resin layer **35**B as a hot-melt adhesive. The element structuring unit **40***a* and the element structuring unit **40***b* are joined together by the adhesive **13** that is applied to the upper surface side of the corrugated ridge portion T of the spacing member **35** included in the element structuring unit **40***a*. The thermal-adhesion-type resin layers **35**B that function as the hot-melt adhesive exhibit insolubility to the water-soluble moisture absorbent that has been added to the partition members **1** or an aqueous solution of the water-soluble moisture absorbent. In other words, while the thermal-adhesion-type resin layers **35**B are in an unhardened state, the water-soluble moisture absorbent with which the partition members **1** are impregnated is not able to dissolve into the thermal-adhesion-type resin layers **35**B. After the thermal-adhesion-type resin layers **35**B are hardened, the water-soluble moisture absorbent and an aqueous solution of the water-soluble moisture absorbent is not able to seep into the thermal-adhesion-type resin layers **35**B.

[0089] For example, in the case where the element structuring units **40***a* and **40***b* are manufactured by using a single-facer apparatus, it is possible to melt the thermal-adhesion-type resin layers **35**B by using a corrugator or a press roller included in the single-facer apparatus as a heat source. Generally speaking, resins expand or shrink only a little when absorbing moisture. Thus, when the thermal-adhesion-type resin layers **35**B are configured so as to be thick, it is possible to inhibit deformation caused by expansion or shrinkage of the spacing members **35**. As a result, it is possible to enhance workability in the manufacturing process of the element structuring units and in the process of manufacturing the total heat exchange element by stacking the plurality of element structuring units in the manner of layers.

[0090] In the total heat exchange element in which the joining mode for the partition members **1** and the spacing members **35** as described above is used, for the same reasons that are explained in the first embodiment about the total heat exchange element **20**, it is easy to obtain a total heat exchange element having high latent heat exchange efficiency. Further, it is also easy to structure an air-conditioning apparatus, a ventilator, or the like that has high reliability by using the total heat exchange element. In addition, it is easy to reduce the time required to manufacture the total heat exchange element and to reduce the input energy required to manufacture the total heat exchange element. Consequently, it is easy to reduce the costs and to reduce environmental burdens on the surrounding environment.

EXAMPLES

[0091] In the following sections, the total heat exchange element and the manufacturing method thereof according to an aspect of the present invention will be specifically explained, by using Examples and a Comparative Example.

Example 1

[0092] First, a long element structuring unit member was manufactured by using equipment that is the same as the equipment **120** shown in FIG. **3**, while using, as a material for partition members, a long product obtained by impregnating a specially-processed paper with a predetermined amount of lithium chloride, which is a water-soluble moisture absorbent, the specially-processed paper having been obtained as a result of a process of crushing cellulose fiber (pulp) and having a thickness of approximately 300 μm and an air permeation resistance level of 5000 seconds or higher, and also using, as a material for spacing members, a long product made of white single-side-glazed high-quality paper having a thickness of approximately 80 μm. In this situation, as an adhesive used for joining a corrugated-plate-like product obtained by shaping the material for the spacing members by using a corrugator and the material for the partition members together, an ethylene-vinyl acetate copolymer resin (EVA)-based hot-melt adhesive having an open time (i.e., a usable time) of a number of seconds was used. A melted substance obtained by heating the hot-melt adhesive to approximately 150° C. was applied to the corrugated-plate-like product so that the application amount was approximately 25 g/m^2.

[0093] After that, the element structuring unit member was cut into pieces of a predetermined size so that a plurality of element structuring units were obtained. A hot-melt adhesive having been made of a styrene-ethylene-butylene-styrene block copolymer (SEBS)-based elastomer and having an open time of approximately 20 seconds to 30 seconds was applied to the element structuring units by using equipment that is the same as the equipment **130** shown in FIG. **4**. In this situation, a melted substance was obtained by heating the hot-melt adhesive to approximately 180° C., and the application amount was approximately 45 g/m^2.

[0094] After that, the element structuring units were sequentially stacked in the manner of layers in such a manner that the corrugation stripes of the spacing member in any one of the element structuring units were substantially orthogonal, in a planar view, to the corrugation stripes of the spacing member in another one of the element structuring units that was positioned above or below the one of the element structuring units. Further, the top plate member was stacked on top of the uppermost element structuring unit. After that, the melted substance of the hot-melt adhesive made of the SEBS-based elastomer was hardened so that a total heat exchange element that had the same exterior appearance as the total heat exchange element **20** shown in FIG. **2** was obtained. In this total heat exchange element, the partition members and the spacing members were joined together by using the same joining mode as shown in FIG. **2**.

Example 2

[0095] First, as a material for partition members, a long product was prepared by impregnating a specially-processed paper with a predetermined amount of lithium chloride, which is a water-soluble moisture absorbent, the specially-processed paper having been obtained as a result of a process of crushing cellulose fiber (pulp) and having a thickness of approximately 300 μm and an air permeation resistance level of 5000 seconds or higher. Also, as a material for spacing members, a long product was prepared in which a film of which the main component was polyethylene and had a thickness of approximately 15 μm was attached, by way of thermal fusion bonding, to one of the surfaces of a base material made of a water-resistant paper having a thickness of approximately 85 μm. The film functioned as a thermal-adhesion-type resin layer. Subsequently, the material for the spacing members was shaped into a corrugated-plate-like product by using a corrugator, starting from an end of the material. By using the film as a hot-melt adhesive, the material for the spacing members was joined with the material for the partition members, in such a manner that any portion of the material for the spacing members that had been shaped into the corrugated-plate-like product was subsequently joined with the material for the partition members. Thus, a long element structuring unit member was obtained.

[0096] After that, the element structuring unit member was cut into pieces of a predetermined size so that a plurality of element structuring units were obtained. The element structuring units were stacked in the manner of layers under the same condition as the one used in Example 1, so that a total heat exchange element having the same exterior appearance as the total heat exchange element **20** shown in FIG. **1** was obtained. In this total heat exchange element, the partition members and the spacing members were joined together by using the same joining mode as shown in FIG. **7**.

Comparative Example

[0097] A long piece of flame-retardant paper (corresponding to Grade 2 Flame Retardancy defined in the Japanese Industrial Standards [JIS]) having a thickness of approximately 70 μm was used as a material for spacing members. Also, as the adhesive used for manufacturing a long element structuring unit member and as the adhesive used for stacking a plurality of element structuring units in the manner of layers, a substance obtained by adding water, for the purpose of adjusting the viscosity, to a vinyl-acetate-based emulsion adhesive, which is a water-solvent-type adhesive, was used. Except for these features, a total heat exchange element was manufactured under the same condition as the one used in Example 1. The application amount of the adhesive used for manufacturing the long element structuring unit member was 14 g/m^2. The application amount of the adhesive used for stacking the plurality of element structuring units in the manner of layers was 29 g/m^2.

Evaluations

[0098] For each of the total heat exchange elements that were manufactured as Example 1, Example 2, and Comparative Example, temperature exchange efficiency (i.e., sensible heat exchange efficiency), moisture exchange efficiency (i.e., latent heat exchange efficiency), and total heat exchange efficiency in a high-humidity environment as well as temperature exchange efficiency, moisture exchange efficiency, and total heat exchange efficiency in a low-humidity environment were measured. The levels of exchange efficiency in the high-humidity environment were measured under a condition that was compliant with an exchange efficiency measuring condition (i.e., a summer condition) according to JIS B8628 (total heat exchangers), whereas the levels of exchange efficiency in the low-humidity environment were measured under a condition that was compliant with an exchange efficiency measuring condition (i.e., a cooled-room condition) according to Standard 1060 Rating Air-to-Air Energy Recovery Ventilation Equipment defined by the Air-conditioning and Refrigeration Institute (ARI) in the USA, while using a method that was compliant with JIS B8628 (total heat exchangers). The measured results are shown in a table in FIG. **8**.

[0099] As apparent from FIG. **8**, the temperature exchange efficiency and the moisture exchange efficiency in the high-humidity environment as well as the temperature exchange efficiency in the low-humidity environment were substantially the same for the total heat exchange elements according to Example 1, Example 2, and Comparative Example. In contrast, each of the total heat exchange elements according to Example 1 and Example 2 had a very much higher level of moisture exchange efficiency in the low-humidity environment than the total heat exchange element according to Comparative Example. The reason for these results can be explained as follows: In the total heat exchange element according to Comparative Example, the water-soluble moisture absorbent (i.e., lithium chloride) moved from the partition members into the spacing members, both during the manufacturing process of the total heat exchange element and after the manufacturing process of the total heat exchange element. In contrast, in each of the total heat exchange elements according to Example 1 and Example 2, the water-soluble moisture absorbent (i.e., lithium chloride) hardly moved from the partition members into the spacing members, both during the manufacturing process of the total heat exchange element and after the manufacturing process of the total heat exchange element. It is therefore conjectured that, in each of the total heat exchange elements according to Example 1 and Example 2, the water adsorbing characteristics was improved especially in the low-humidity environment, and the level of moisture permeability therefore increased, because the water-soluble moisture absorbent hardly moved.

[0100] The total heat exchange element and the manufacturing method thereof as well as the heat exchange ventilation device according to aspects of the present invention have been explained through the exemplary embodiments and the Examples. However, the present invention is not limited to the exemplary embodiments described above. For example, to apply the adhesive in an unhardened state, it is acceptable to use any other method (e.g., spraying the adhesive) that is suitable for the properties of the adhesive, instead of using the application roller.

[0101] Further, as long as each of the spacing members is able to hold two partition members with a predetermined interval therebetween, sheets that have been shaped into rectangular corrugations or triangular corrugations or a plurality of plate pieces may be used as the spacing members. In addition, as for the overall shapes of each of the element structuring units and the total heat exchange element, it is possible to select any shape, as necessary, according to the applications of the total heat exchange element to be manufactured and the performances that the total heat exchange element is expected to achieve. Furthermore, besides the exemplary embodiments above, it is possible to apply various changes, modifications, and combinations to the total heat exchange element and the manufacturing method thereof according to any of the aspects of the present invention.

INDUSTRIAL APPLICABILITY

[0102] The present invention is applicable to a total heat exchange element in any mode as long as the total heat exchange element is used in a stationary-type heat exchanger. It is possible to use the total heat exchange element according to the present invention in any of various apparatuses that are used for the purpose of air-conditioning or ventilating buildings, automobiles, vessels, and the like.

1. A total heat exchange element having a stacked-layer structure in which sheet-like partition members added a water-soluble moisture absorbent thereto and spacing members are stacked alternately, the spacing members being joined with the partition members by using an adhesive so as to form air flow passages together with the partition members, wherein

the spacing members have water retention properties, and

the adhesive exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent.

2. The total heat exchange element according to claim **1**, wherein the adhesive is an organic-solvent-based adhesive, a solventless reactive adhesive, or a hot-melt adhesive.

3. The total heat exchange element according to claim **1**, wherein each of the partition members is made of a water retentive material that is impregnated with the water-soluble moisture absorbent.

4. The total heat exchange element according to claim **1**, wherein

each of the spacing members includes a base material made of a water retentive material and a thermal-adhesion-type resin layer disposed on one of surfaces of the base material, and

the thermal-adhesion-type resin layer functions as the adhesive used for causing the spacing members to be joined with the partition members.

5. The total heat exchange element according to claim **1**, wherein the water-soluble moisture absorbent is a deliquescent alkali metal salt or a deliquescent alkali earth metal salt.

6. A manufacturing method of a total heat exchange element having a stacked-layer structure in which sheet-like partition members added a water-soluble moisture absorbent thereto and spacing members are stacked alternately, the spacing members being joined with the partition members by using an adhesive so as to form air flow passages together with the partition members, the manufacturing method comprising:

a unit manufacturing step of obtaining a plurality of element structuring units in each of which one of the partition members and a corresponding one of the spacing members each being made of a water retentive material are joined together by using the adhesive; and

a layer stacking step of joining the element structuring units together by using an adhesive and obtaining the total heat exchange element in which the plurality of element structuring units are stacked in layers, wherein

the adhesive used at the unit manufacturing step and the adhesive used at the layer stacking step each exhibits insolubility to the water-soluble moisture absorbent or an aqueous solution of the water-soluble moisture absorbent.

7. The manufacturing method of a total heat exchange element according to claim **6**, wherein the adhesive used at the unit manufacturing step and the adhesive used at the layer stacking step are each an organic-solvent-based adhesive, a solventless reactive adhesive, or a hot-melt adhesive.

8. The manufacturing method of a total heat exchange element according to claim **6**, wherein each of the partition members is made of a water retentive material that is impregnated with the water-soluble moisture absorbent.

9. The manufacturing method of a total heat exchange element according to claim **6**, wherein

each of the spacing members includes a base material made of a water retentive material and a thermal-adhesion-type resin layer disposed on one of surfaces of the base material, and

the thermal-adhesion-type resin layer is used as the adhesive at the unit manufacturing step.

10. The manufacturing method of a total heat exchange element according to claim **6**, wherein the water-soluble moisture absorbent is a deliquescent alkali metal salt or a deliquescent alkali earth metal salt.

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