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(54) A humidifier.

(57) Humidifying apparatus is provided which includes a hollow, envelope-like base made of a porous polymeric material (1), which material is both water vapor permeable and liquid-water-impermeable. The base component is superposed with an adjacent, corrugation-like, void forming sheet of material (2) to form a composite structure which is wound to a spiral configuration. The envelope base component and the corrugated void forming sheet are affixed together by means of a filament (3) wound about their external periphery. The apparatus includes means (4) for supplying liquid water into the hollow base envelope and supplying dry air into and through the voids of the void forming sheet (2), whereby humidification of the dry air passing therethrough is effected. The envelope component (1) is preferably made of porous, expanded polytetrafluoroethylene.

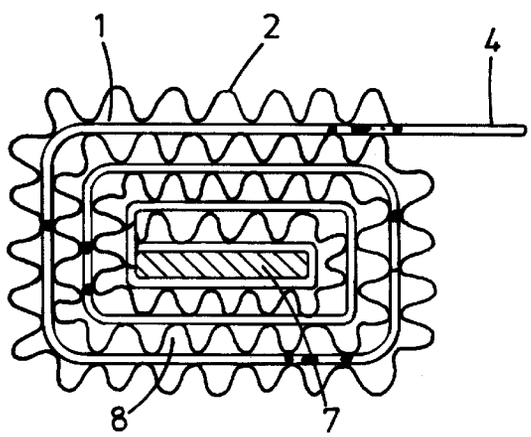

FIG.1

EP 0 661 503 A2

The present invention relates to a humidifier that is installed in the dry air outlet of air conditioning equipment and the like.

Conventional humidifying apparatus has been proposed, e.g. in Japanese Laid-Open Patent Application 61-175421. In that application, a humidifier having a hollow membrane envelope having a water supply inlet and a water discharge outlet at its ends is superposed with a corrugated, void forming sheet material, and these components are wound together spirally around a core having a rectangular cross section, thus forming an assembly whose overall shape is rectangular when viewed from the front. In this known assembly, ventilation passageways are formed by the voids in the void forming corrugated sheet adjacent the hollow envelope. A porous membrane made from a hydrophobic macromolecular material through which water vapor passes easily but liquid water will not pass is disclosed to be suitable for the hollow envelope membrane material.

The above-mentioned spiral assembly is housed in a generally rectangular case and installed as a humidifier at the dry air outlet of an air conditioner, a building air handling unit, or other similar air conditioning apparatus. When the hollow portion of the hollow envelope is filled with water and dry air is passed through the ventilation component, the dry air is humidified by the water vapor that passes through the porous walls of the hollow envelope.

However, in the apparatus according to the above-mentioned application, the hollow envelope, which is filled with water, and the void forming corrugated material are not fixed together, so misalignment of the components can occur during assembly, and readjusting this misalignment requires extra time and makes the hunidifying process more difficult. Also, if the spiraling of the superposed envelope material and the void forming material around the core is not carried out properly, the hollow envelope material can extend outwardly from between the sheets of the void forming material owing to elongation and sagging of the hollow envelope membrane material when water has been supplied to the hollow portion of the envelope after the assembly of the apparatus, and this misalignment can cause a variety of problems. This misalignment can also occur as a result of vibration during the assembly or shipping of the humidifier, or as a result of the body weight of the hollow envelope material itself after it has been set in an air conditioning apparatus and filled with water, or as a result of vibration, e.g. from the motor of the air conditioner, etc., after the humidifier has been put in place, or as a result of other similar causes.

In an effort to solve this known problem, it has been proposed in Japanese Laid-Open Utility Model Application 62-14241 that the hollow membrane envelope, the void forming corrugated material, and the core all be fixed using an adhesive agent on the front or back of the humidifier. However, this method of fixation is employed using a hydrophilic adhesive agent, the adhesive agent penetrates the surface and interior of the hollow membrane envelope material which, as stated, is composed of a material that is both permeable to water vapor and impermeable to liquid water. This adhesive penetration causes liquid water to pass through and leak, resulting in a shortened usable life for this known apparatus.

The objective of the present invention is to overcome the above-mentioned problems encountered with those previously known humidifiers and to provide a humidifier that is easy to assemble, whose constituent components cannot become misaligned easily, and which has a long usable life.

According to the present invention there is provided humidifying apparatus which includes a hollow, envelope-like base made of a porous polymeric material, which material is both water vapor permeable and liquid-water-impermeable. The base component is superposed with an adjacent, corrugation-like, void forming sheet of material to form a composite structure which is wound to a spiral configuration to form a ventilation structural component. The envelope base component and the corrugated void forming sheet are affixed together by means of a filament wound about their external periphery. The apparatus includes means for supplying liquid water into the hollow base envelope and supplying dry air into and through the voids of the void forming sheet, whereby humidification of the dry air is effected. The envelope component is preferably made of porous, expanded polytetrafluoroethylene.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Fig. 1 is a schematic elevational view of the humidifier of the invention spirally wrapped about a rectangular core.

Fig. 2 shows the key components of the humidifier according to the invention shown in Fig. 1 in its flat, unwrapped configuration prior to wrapping it about the core.

More specifically, the present invention provides a humidifier in which a hollow envelope-like membrane material, preferably of porous polytetrafluoroethylene, that is both permeable to water vapor and impermeable to liquid water is superposed with a corrugated, void forming material and this composite is wound into a spiral configuration, whereby a ventilation component is formed between the envelope and the void forming material. Humidification is achieved by supplying water into the envelope and supplying dry air to and through the voids of the ventilation component. The humidifier is constructed such that the hollow envelope membrane material and the void forming corrugated sheet material are fixed together by being wound about their peripheries with a fila-

ment in order that misalignment caused by vibration, tare weight and the like, during assembly, after assembly, and during shipping can be effectively prevented. Misalignment will not occur even if the product is subjected to fairly rough handling. Handleability is extremely good and, because the attachment is not achieved with an adhesive agent, there is little possibility of water permeation or water leakage. These advantages allow the usable life of the apparatus to be extended over previously known humidifiers.

The invention provides a humidifier in which a hollow envelope material of porous expanded polytetrafluoroethylene, which is permeable to water vapor but impermeable to liquid water, is superposed together with a corrugated, void forming sheet material and then wound into a spiral configuration, thereby forming a ventilation structural composite. Humidification is achieved by supplying water to the interior hollow of the envelope and supplying dry air to and through the voids of the ventilation component. A unique feature of this structure is that the hollow envelope membrane material and the void forming corrugated sheet material are fixed together by being wound about their peripheries with a filament.

As shown in the accompanying drawings, Figure 1 is a schematic end elevation of the structure of the humidifier in one example of the present invention. Figure 2 shows the spiral assembly of Figure 1 depicted in an unwound state. As shown in Figure 2, the void forming sheet material **2** is laid over the hollow envelope-like membrane material **1**, and these two components are fixed together by being wound at a suitable winding pitch with filament **3**.

Referring to Figure 2, the envelope-like hollow membrane material **1** is formed by overlaying two rectangular sheets **1A** and **1B** and sealing them together at their edges **1S** such as by thermal fusion or by using an adhesive. A water supply tube **4** is inserted into one end of the opening of envelope **1** as shown, and a hollow, air bleed tube **5** is inserted in the other end. This tube **5** extends into but not through the hollow portion of envelope **1**. Flexible solid rods **6,6** are inserted into the envelope and preferably extend through the envelope, thereby providing a channel through which input water is directed. The water supply tube **4** is attached to one end of the hollow envelope membrane material **1**, and air bleed tube **5** is attached to the other end. The water channel support rods **6** are positioned on both sides in the lengthwise direction as shown inside the hollow envelope **1**. After the envelope **1** and the void forming material **2** have been superposed and affixed together by winding with filament **3**, this composite assembly is spirally wound around a suitable core, preferably having a rectangular cross section as shown in Figure 1, to produce a substantially rectangular wound configuration. This results in ventilation components **8** being formed between the adjacent walls of envelope **1** and void forming sheet material **2**. This assembly is installed in a casing to complete the humidifier assembly.

The envelope material **1** of the present invention is preferably formed using porous, expanded polytetrafluoroethylene (herein referred to as porous PTFE) as the base material. This porous PTFE generally has a mean pore diameter of 0.02 to 15 μm and a thickness of about 0.025 to 5 mm, and allows water vapor to permeate therethrough but blocks the permeation of liquid water.

The porous polytetrafluoroethylene resin used as the base material for the hollow membrane material **1** is manufactured, for example, by the methods discussed in U.S. Patents 3,953,566 and 4,187,390. Specifically, a liquid lubricant such as solvent naphtha, white oil, or other lubricant such as hydrocarbon oil, petroleum ether, or the like is admixed with a polytetrafluoroethylene resin having a high degree of crystallinity of approximately 95% or more to produce a pre-mold. The mixing ratio is about 20 parts liquid lubricant per 80 parts polytetrafluoroethylene, for example. Next, this pre-molding is extruded in the form of a sheet or rod from the die of an extruder to produce a molded article. The molded article thus obtained, either with or without the liquid lubricant having been removed, is drawn or stretched at a high rate, at least above 10% per second, in an unsintered state at an elevated temperature of 327°C or below. This drawn product is then subjected to a heat treatment in the drawn state at 200 to 390°C, which treatment prevents shrinkage and produces the desired, expanded porous polytetrafluoroethylene product. The porous polytetrafluoroethylene product obtained in this manner consists of extremely fine fibers called fibrils and extremely fine nodules called nodes that link these fibrils. Extremely fine interconnected pores are present between these fibrils and nodes, forming a so-called continuous porous structure.

The base envelope material may also include a covering film of a moisture permeable hydrophilic resin formed on the surface of the porous PTFE membrane. This cover film may be formed by lamination over the porous PTFE membrane, or may be a continuous covering film in which the inside of the porous PTFE membrane is impregnated with the moisture permeable resin. The covering film may impregnate or be laminated over the outside of the envelope material **1**, or it may impregnate or be laminated over the inside of the hollow envelope membrane material **1**. The hydrophilic continuous film discussed in U.S. Patent 4,194,041, for example, can be used as this continuous covering film. A macromolecule that has hydroxyl groups, carboxyl group, sulfonic acid groups, amino groups, or other hydrophilic groups and is water-swellable and water-insoluble can be used favorably as this moisture permeable resin. Specific examples of such hydrophilic resins include at least partially crosslinked polyvinyl alcohol, cellulose acetate,

cellulose nitrate, and other hydrophilic polymers, and polyamino acids, polyurethanes, and hydrophilic fluorine-containing polymers. When heat resistance, chemical resistance, and workability are considered, a polyurethane resin or a fluorine-based moisture permeable resin is preferred.

The base material can also have a reinforcing fabric applied to the porous PTFE membrane alone or to a porous PTFE membrane on which the cover film of hydrophilic moisture permeable resin has been formed. In this case, a nonwoven fabric, a woven fabric, a knit fabric or the like can be used as the reinforcing fabric, and this fabric may be positioned on either the inside or outside of the base material.

The hollow envelope **1** is produced by superposing two sheets **1A** and **1B** having the above structure and molded in the form of belts or sheets, and then joining the edges of the sheets in their lengthwise direction with an adhesive agent or by thermal fusion to create the hollow envelope-like structure **1**. An envelope-like base may also be produced by winding a sheet of the desired material around a core in a spiral fashion or rolling the sheet like cigarette paper, joining the overlapping portions of the sheet with an adhesive agent or by thermal fusion, and then removing the core. Also, a uniform molded paste produced by impregnating a polytetrafluoroethylene resin with a liquid lubricant, as above, may be extruded directly from a die and molded into a tube, and then drawn, sintered and flattened to produce a hollow envelope-like base.

The void forming corrugated sheet material **2** of the present invention can be polyethylene, polypropylene, polyvinyl chloride, or the like, having a thickness of 0.1 to 1 mm.

The filament **3** can be a natural fiber such as cotton, or a synthetic such as nylon, polyester, or other synthetic fiber, or metal, or a composite of these materials. Its size, in the case of a synthetic fiber, is preferably about 100 to 1000 denier. The winding configuration thereof is prefereably a spiral winding, and the winding pitch should be about 1 to 100 mm, with about 10 to 30 mm being preferable.

The air bleed tube **5** is made from a material that is permeable to air but impermeable to liquid water, such as porous expanded PTFE, and is installed so as to assure rapid water-air exchange when the hollow portion of the hollow envelope base material **1** is filled with the humidifying liquid water.

The water channel support rods or beads **6** are formed by integral fusion with the membrane sheets by means of a polyurethane resin adhesive, for example, in order to ensure water passage therethrough.

As an example according to the invention, a hollow envelope of porous expanded PTFE was superposed with a void forming corrugated sheet-like material of polyethylene, and these two components were fixed together by spirally winding, at a winding pitch of 20 mm, a 400-denier filament composed of polyester. This composite assembly was then spirally wound around a rectangular core to form a coil, which produced the configuration shown in Figure 1. This wound assembly was then set in a casing, thereby completing the humidifier of the present invention.

The humidifier produced in this manner had substantially no misalignment between the void forming sheet material and the hollow envelope base material and was extremely easy to work with. The assembly time for this device was about one-third that required in the past for known constructions. After assembly, the unit was filled with humidifying water at a water pressure of 0.1kg/cm^2, after which the water pressure was relieved, the humidifying water drained, and a check was made for misalignment. It was found that this humidifier device suffered virtually no misalignment during either the supply of humidifying water or after the drainage of humidifying water. This is in sharp contrast to conventional apparatus, in which swelling of the hollow envelope and misalignment occurred and proper alignment could not be restored after the humidifying water had been drained. The ventilation component of the humidifier was also examined. There was no significant change in terms of pressure loss at either the inlet or the outlet using the present humidifier.

The present invention may also be used in conjunction with an adhesive agent fixing method as discussed in Japanese Laid-Open Utility Model Application 62-14241. In this case, only a small amount of adhesive agent need be used, and the advantages of both fixing methods are available.

Claims

1. Humidifying apparatus comprising a hollow, envelope-like base component of a porous polymeric material which is both water vapor permeable and liquid-water-impermeable, said base component being superposed with an adjacent corrugation-like void forming sheet of material to form a composite structure, said composite structure being wound to a spiral configuration, thereby forming a ventilation component between said envelope-like component and said void forming sheet, wherein said envelope-like base component and said void forming sheet are affixed together by means of a filament wound about them, said apparatus including means for supplying liquid water into said hollow base component and supplying dry air into and through the voids of said void forming sheet, whereby humidification of said dry air is effected.

2. Apparatus as claimed in claim 1, wherein said base component is porous, expanded polytetra-

fluoroethylene.

3. The apparatus as claimed in claim 1 or 2, wherein said void forming sheet is a water impermeable material of polyethylene, polypropylene or polyvinyl chloride.

4. Apparatus as claimed in any preceding claim, wherein said filament is of cotton, nylon or polyester.

5. Apparatus as claimed in any of claims 1 to 3, wherein said filament is a metal wire.

6. Apparatus as claimed in any preceding claim, wherein said base component has a continuous coating thereon of a hydrophilic water-vapor permeable material.

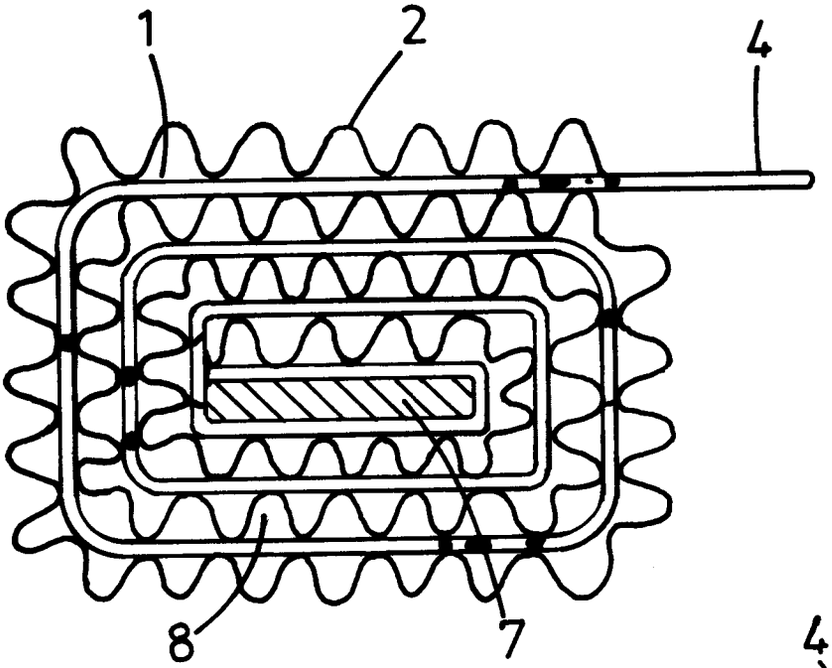

FIG. 1

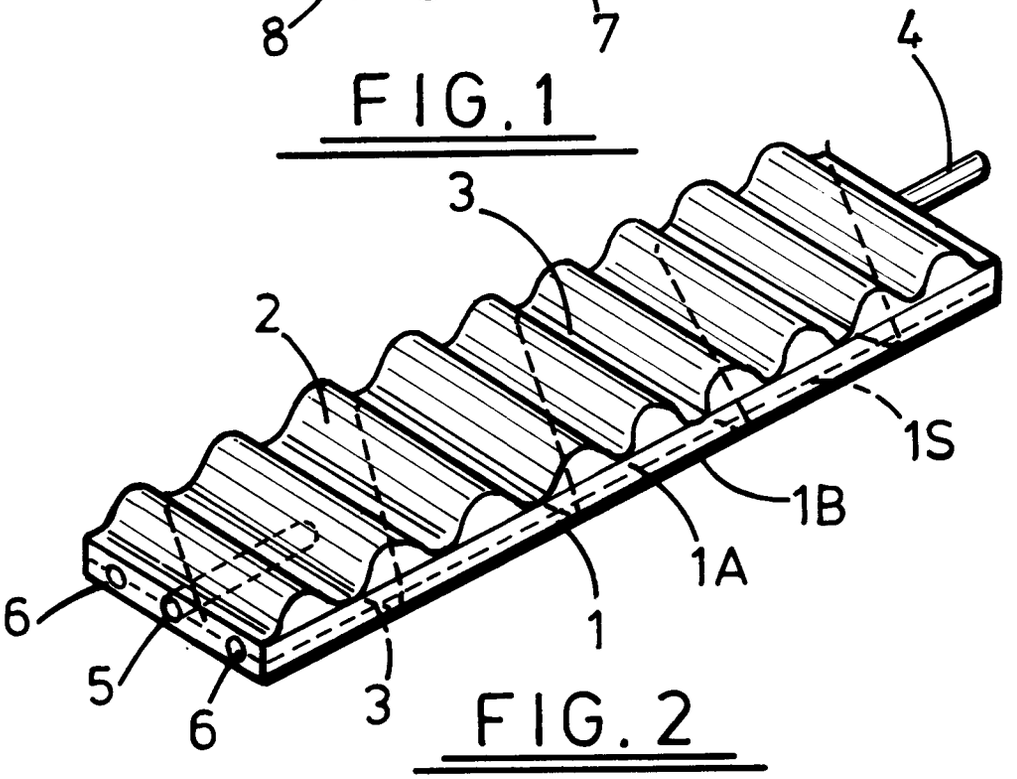

FIG. 2