

AIR COOLING AND AIR DEHUMIDIFYING MODULE COMPRISING CAPILLARY TUBE MATS AND METHOD OF USING IT

Description

The invention relates to an air cooling and air dehumidifying module with a heat exchanger element comprising plastic capillary tube mats which are shaped so as to form a compact packet with a virtually cuboid external shape, which cools and dehumidifies the air flow directed through the mat packet when cold water is fed through the capillary tubes. The invention further relates to a method of operating the air cooling and air dehumidifying module in combination with a cooling ceiling. The purpose of this type of solution is to cool a room and dehumidify the air in the room on a decentralised basis.

Compact water/air heat exchangers are generally made from metal, in which case aluminium and copper are used by preference due to their high capacity to conduct heat. These materials are expensive, require a lot of processing work and above all produce condensate in most applications, often leading to corrosion.

As a means of avoiding these disadvantages, it has been acknowledged that plastic capillary tube mats are very suitable as a means of providing a heat exchange surface. They are very versatile in terms of their use, for example for shaping making cooling and heating ceilings, suspended cooling panels, etc., which simultaneously form enclosure surfaces of a room. The heat exchange takes place by heat conduction, convection and radiation. These constructions cause a room to be cooled but they can and should not produce intensive air cooling as a result.

For the special application of cooling air by convection, one known approach (patent specification DE 198 06 207 C2) is to dispose capillary tube mats in a predominantly flat arrangement in a shaft so that the air circulation takes place between two vertically spaced apart openings due to the differences in density between the air in the shaft and that in the room. This also results in the concept of silent cooling. However, the heat exchanger will only operate at an appropriately high vertical shaft height, the air flow is

relatively small and the efficiency is therefore limited.

In another known construction (DE 198 31 918 C2), similar to the one described above (in DE 198 06 207 C2), the top shaft opening communicates with the external air and the air quality in the room is improved by introducing conditioned external air.

Another known approach is to use plastic capillary tube mats for cooling and heating rooms and/or water baths (DE 197 51 883 C2), which, amongst other things, also contain a spiral-shaped, wound plastic capillary tube mat. Characteristic of this construction is a foil disposed between the capillary tube mats, which has projections (protuberances), by means of which passages are formed. As one flow of substance flows through the capillary tube mat, the second flow of substance is directed through the passages formed by the foil. From a hydraulic point of view, the high pressure loss which occurs due to the flow resistance on the foil is a particular disadvantage. From a thermodynamic point of view, the solution based on the spiral-shaped winding has various disadvantages. In certain regions, the foil lies against the capillary tubes, which means it is not possible to produce a free flow round them, thereby reducing the external coefficient of heat exchange. The result of an arrangement with a capillary mat with a single inlet for the liquid flow is a cross-counter flow guide system with a low proportion of counter-flow due to the fact that the secondary flow of substance is axially directed. If opting for several inlets, the pressure loss in the capillary tube mat rises sharply. The temperature of the externally directed flow of substance is not uniform across the cross-section of the heat exchanger, which can be a particular disadvantage at the outlet.

The disadvantages outlined above are avoided by the solution described in DPMA 103 13 384.4 (European patent application number 03016203.6), which is characterised by plastic capillary tube mats disposed in a spiral shape and with a radial air inlet. The disadvantage of this approach, however, is the large amount of space required due to the cylindrical heat exchange geometry, which means that it can be used for air-conditioning purposes in office and living spaces to a only limited degree.

In terms of practical applications, the known solutions outlined above are controlled on

the basis of room temperature, which means that there is no active possibility of controlling the air humidity in the room.

The underlying objective of the invention is to satisfy the objectives for the air cooling and air humidifying module set out below:

- a large surface should be achieved in the smallest possible space;
- in terms of its external dimensions, the heat exchanger element should be designed so that it can be integrated in devices and/or spaces available for construction - for example in ceiling cavities above cooling ceilings;
- the construction of the module and especially the heat exchanger element must lend itself well to maintenance and it must also be easy to replace the heat exchanger element;
- a material that is corrosion-proof and not susceptible to incrustation should be used for the heat exchanger surface;
- it should be possible to direct the flow in a thermodynamically conducive arrangement;
- it should be possible to achieve intensive air cooling and air dehumidification due to a high convective heat exchange at the surface of the heat exchanger element;
- it must be possible to control output according to room temperature or according to air humidity in the room;
- if the air cooling and air dehumidifying module is used in conjunction with a cooling ceiling or with other cooling surfaces in the room, it must be possible to control the temperature of the room actively and simultaneously also the air humidity of the room.

The set objectives are achieved by the invention on the basis of the characterising features defined in claims 1 and 26. A material corrosion-proof which is not susceptible to incrustation is used for the heat exchanger surface because plastic capillary tube mats are used. A good convective heat exchange is achieved at the heat exchanger surface through the transverse intake of the capillary tubes due to the short thermodynamic flow length achieved by the small diameter of the capillary tubes (as a rule smaller than 6 mm) and due to the circulation rate through the compact mat packet. This obviates the need for fin arrangements on the heat exchanger surfaces which are generally otherwise needed for heat exchangers, thereby providing an effective option for cleaning. A large surface is achieved in the smallest possible space due to the compact folding and/or winding technology so that the external geometry of the packet more or less assumes the shape of a cuboid. This fact offers ideal conditions for use in devices, in structurally restricted spaces, such as in ceiling cavities for example, and for replacing the heat exchanger element.

A permanent shape can also be imparted to the mat packet solely and/or additionally by making use of the memory effect - for example by a thermal pre-treatment.

One advantage in terms of the efficiency of this heating engineering is the fact that the air is directed through the mat packet in such a way that it primarily circulates in counter-flow with the water circulation.

It is of particular advantage from a construction and heating engineering point of view to use mat packets with a core region which is identical to the pressure chamber for distributing the air because this solution takes up a particularly small amount of space and a priori results in a thermodynamically conducive counter-flow.

Other advantageous features of the air cooling and air dehumidifying module are the arrangement of air distribution systems in the pressure chamber, the use of displaceable air inlet fittings in the pressure chamber and the design of the housing, which is conducive to introducing air into the room in a specific way depending on where the module is disposed in the room. For example, a source air passage can be formed

by opting for a specific perforation pattern in the housing and using an air flow direction system, or a rectangular free jet can be generated by integrating air circulation elements of a slotted shape or alternatively an air flow with a higher turbulence can be created by means of a helical air passage.

It is also of advantage to combine the installations outlined above for taking in air, for distributing air or providing a passage for the air with systems for filtering the air.

The fact that the mat packet with its core region is fitted horizontally and the latter is used as a pressure chamber offers the option of an extremely flat construction, which lends itself particularly well to integration in ceiling cavities, e.g. above cooling ceilings or suspended cooling panels.

In one advantageous embodiment, a complete housing is dispensed with and if mat packets with a core region which can be used as a pressure chamber are employed, only blanking plates need be used for the core region, and at least one blanking plate is provided with an orifice for the incoming air.

Sealing bodies are built into the lateral ends of the mat packets in order to prevent or reduce bypass air flows, which conditions the air flow uniformly as it circulates.

In the case of larger pressure chambers or those with a geometrically pronounced, one-sided extension and/or for controlling the output of the module in stages, it is of advantage to install several fans and/or shaped pieces which help to direct and deflect the air.

The air flow distribution in the room to be air-conditioned can be further improved by encasing the mat packet in a foil with appropriate perforations or an appropriate fabric.

One special option for improving performance, i.e. for cooling air and dehumidifying air, is to use several mat packets disposed one after the other in the air flow in series, comprising folded and/or wound plastic capillary tube mats which are connected in counter-flow at the water end. To improve performance still further, several cold water

inlets into the consecutive mat packets may also be provided.

In another embodiment, external air is directed partially or exclusively into the pressure chamber, as a result of which the external air flow which must necessarily be hygienic also undergoes a temperature and/or humidity change.

In order to improve conditions for users of the room from a heat and physiological point of view, it may be of advantage to treat specific room surfaces in a special way, for example to cool warm window or ceiling surfaces. To this end, the modules proposed by the invention are disposed so that an intensive air flow takes place along the pane, wall, etc., to be conditioned, if necessary using the Coandă effect.

Furthermore, the air cooling and air dehumidifying module may also be used during periods when it is necessary to heat the room by using hot water, in which case it assists or fully takes over the function of heating the room.

The output of the modules can be controlled by all known methods and combinations of them (varying the water inlet temperature, varying the water flow, varying the air flow volume, e.g. by speed control, shutting down individual fans, using gravitational force, etc.).

The method is also designed to increase efficiency from the point of view of primary energy use because, if the system is designed to operate at a low cold water temperature - which causes dehumidification due to condensation of the water vapour in the air as desired - and as high as possible a cold water temperature is used for the cooling ceiling, the room is cooled with a low exergic flow - for example due to a high proportion of ambient energy.

Special additional features are used which permit a practical and space-saving deployment of the air cooling and air dehumidifying module in conjunction with different types of cooling ceilings. In the case of open cooling ceilings and suspended cooling panels, the ambient air can expediently be drawn from directly underneath the room ceiling, i.e. via the cooling surface.

If the system proposed by the invention is to be fitted in large rooms or in individual rooms with a cooling load curve that is identical as a function of time, it is of practical advantage to form control zones for a group of air cooling and air dehumidifying modules in conjunction with the co-operating cooling ceilings and/or suspended cooling panels. Depending on the local extension of the control zones, it is of practical effect to determine the control variables comprising the room temperature and air humidity of the room on the basis of mean values obtained from several measurement values.

One advantageous solution for adapting output is to opt for a time control system, which is operated in anticipation of expected high load changes.

In order to save energy, it is of practical advantage to adapt the method so that an inactive range - a so-called energy zero band - lies between the switching stages of the control system, in which case the room is not cooled and the air is not dehumidified within fixedly defined threshold values or one of these activities is deliberately dispensed with.

Another option for simplifying automatic control is to regulate the room temperature only and operate dehumidification of the air on a passive basis so that the humidity of the room fluctuates freely within specific ranges based on a calculation of the humidity loads and the resultant dehumidification output calculated beforehand.

Of particular advantage in terms of economic use of energy resources is an automatic control system based on the objective of minimum exergic operation whilst producing optimum heat and physiological conditions in the room. This may be achieved by using a micro-computer, for example, which as a priority operates energy consumption based on water at a temperature as close to that of the room as possible and optimises the power distribution between the air cooling and air dehumidifying module and the cooling ceiling or suspended cooling panel.

It may also be of practical advantage to connect the water-end air cooling and air dehumidifying module and the cooling ceiling or suspended cooling panel in series

because the cold water at low temperature causes dehumidification in the module and the higher return temperature out of the module serves as an intake for the cooling ceiling or suspended cooling panel. By carefully adapting the output, which is determined by the module size and the ceiling size, condensate can be prevented from forming on the cooling surfaces of the room.

The invention will be explained in more detail below with reference to examples of embodiments illustrated in the drawings.

Of these:

Fig. 1 shows schematic cross-sections through the mat packet, which is made up of one or more plastic capillary tube mats using a folding and/or winding technology, thereby resulting in an external geometry resembling a cuboid shape;

Fig. 2 shows different schematic cross-sections of the air cooling and air dehumidifying module with special arrangements of the mat packets and the pressure chamber;

Fig. 3 is a schematic diagram of the water-end, serial connection of the mat packets inside the air cooling and air dehumidifying module for directing the flow thermodynamically with a high proportion of counter-flow;

Fig. 4 is a schematic vertical section through an air cooling and air dehumidifying module with a mat packet with a core region which is used as a pressure chamber, and a guide system for the air and water flow in counter-flow;

Fig. 5 is a schematic longitudinal section through Fig. 4;

Fig. 6 is a schematic vertical section through an air cooling and air dehumidifying module with a mat packet with a core region, disposed horizontally in order to reduce the fitting height;

Fig. 7 is a schematic longitudinal section through Fig. 6 with a diagram illustrating an

example where sealing bodies are used;

Fig. 8 is a schematic longitudinal section through an air cooling and air dehumidifying module with a mat packet with a core region without a complete housing but with lateral blanking plates for the mat packet and the specific feature of a two-sided air intake in the axial direction;

Fig. 9 is a detail from a schematic longitudinal section through an air cooling and air dehumidifying module where air is drawn from the room from underneath by means of a fan;

Fig. 10 is a detail from a schematic longitudinal section through an air cooling and air dehumidifying module where air is drawn from the room from above by means of a fan and integrated fittings for deflecting the air with low pressure losses;

Fig. 11 is a schematic diagram illustrating the disposition of air cooling and air dehumidifying modules and a closed cooling ceiling with the systems for supplying cold water and characteristics of the automatic control principle;

Fig. 12 is a schematic diagram of an air cooling and air dehumidifying module, downstream of which a suspended cooling panel is connected at the water end, and the output is automatically controlled on the basis of the room temperature (variant X may also be replaced by variant Y);

Fig. 13 is a schematic diagram of an air cooling and air dehumidifying module, downstream of which a suspended cooling panel is connected at the water end, and the output is automatically controlled on the basis of room temperature and the maximum permissible room air humidity;

Fig. 14 is a schematic diagram illustrating the disposition of air cooling and air dehumidifying modules in conjunction with an open cooling ceiling, and air is drawn from the ceiling cavity;

Fig. 15 is a schematic diagram illustrating the disposition of the air cooling and air dehumidifying module in conjunction with a suspended cooling panel, and air is drawn out of the room from underneath the suspended cooling panel;

Fig. 16 is a schematic diagram illustrating the disposition of the air cooling and air dehumidifying module in conjunction with an active and a passive suspended cooling panel, and air is drawn out of the room through the ceiling cavity;

Fig. 17 is a schematic diagram illustrating the disposition of the air cooling and air dehumidifying module in conjunction with a suspended cooling panel, and air is drawn out of the room through the top ceiling cavity and air is re-introduced via the suspended cooling panel;

Fig. 18 is a schematic diagram illustrating the disposition of an air cooling and air dehumidifying module for conditioning the air of the room directly and another air cooling and air dehumidifying module which operates by introducing external air.

Example 1:

As illustrated in Fig. 1, shape 1 is imparted to the compact mat packet comprising plastic capillary tube mats by folding or shape 2 or 3 is imparted by winding, so that the external dimensions virtually assume the geometry of a cuboid.

Example 2:

As illustrated in Fig. 2, the mat packets 1, 2 or 3 illustrated in Fig. 1 are disposed in a housing 11, thereby forming a pressure chamber 12, from out of which the air flow 10 passes through the mat packets into the room 9 to be air-conditioned. Cold water is circulated through the capillary tube mats forming the mat packet, so that the air flow 10 is cooled and also dehumidified (dried) when there is a drop below the dew point temperature. Any condensate which drops out is collected in the condensate catchment container 13, from where it is removed by known methods, for example by pumping it out. An air pressure exists in the pressure chamber 12 which is higher than that in the room 9. This is achieved by the action of a fan 17, which removes the air flow 19 from the room 9 and conveys it into the pressure chamber 12.

Example 3:

Fig. 3 illustrates one option for thermodynamically improving the operating characteristic, because several mat packets, for example of design type 2, are connected in series in the path of the air flow 10 and also the cold water is fed in counter-flow. To this end, the intake 14 lies outwards, the return 14a lies inwards and the cold water connecting lines 16 are disposed as illustrated in Fig. 3.

Example 4:

As illustrated in Fig. 4 and Fig. 5, using a mat packet of design type 3 offers the possibility of using the core region 6 as a pressure chamber 12. The advantage of this variant is that as the cold water flows from outside to the interior, as indicated by the connectors 14 and 15, there is always a thermodynamically optimum counter-flow. A very compact construction of the module is also achieved.

Example 5:

By contrast with example 4, Fig. 6 and Fig. 7 illustrate the mat packet based on design type 3 but fitted horizontally. Due to the low height, the air cooling and air dehumidifying module is particularly suitable for integrating in ceiling cavities, for example for use in conjunction with cooling ceilings or suspended cooling panels. The air flow 10 is able to pass into the room from three sides and the condensate catchment container 13 extends at least across the dimension 5. A different option is possible if the condensate catchment container is of a smaller design, for example reduced to a gutter, and the falling condensate is introduced via baffle surfaces disposed in a funnel-shaped arrangement. Fig. 7 also illustrates an example of integrated sealing bodies 21 to prevent leakage flows of non-conditioned air. It may also be practical to integrate these if mat packets abut laterally with one another.

Example 6:

Fig. 8 to Fig. 10 illustrate details showing various dispositions of the fan or fans 17. The air flow 19 out of the room 9 may enter from all sides of the housing in principle and then be conveyed into the pressure chamber 12. The design of the fans 17 may be of any known type, although roller fans and axial fans are preferred. The advantage of

roller fans is that they fill the pressure chamber with the air flow across a wide intake surface. Fig. 8 illustrates a solution with two fans 19. This variant ensures that the air flow 10 is distributed uniformly through the mat pack in the event of a long packet length 20. One fan can also be switched off in order to provide an automatic control system in stages. For this reason, it may also be useful to use additional fans 17. Fig. 8 illustrates the direct mounting of the fans on the blanking plate 18a, for example by mounting flanges. Fig. 9 shows the fan 17 integrated in the housing 11. Fig. 10 illustrates the solution resulting in low pressure losses achieved by fittings to direct the air. These fittings may be connected to the housing 11, the fan 17 or, as illustrated, to the blanking plate 18b by a non-positive, positive and/or material connection.

Example 7:

Fig. 11 illustrates one theoretical option for providing air cooling and air dehumidifying modules 22 in conjunction with a cooling ceiling 24 as well as their cold water connectors 14, 15, 14a, 15a and the automatic control system. From the point of view of exergic operation, it is generally of advantage if the air cooling and air dehumidifying module 22 is connected to a cold water network of low temperature which causes the water vapour from the air to condense on the capillary tube surface when there is a drop below the dew point and the cooling ceiling 24 is connected to a cold water network of higher temperature. This enables the cooling ceiling to be operated during a large period of the year by means of ambient energy, for example, which is picked up via a cooling tower or is drawn from an earth collector. The automatic control should preferably be undertaken by two control circuits. The air cooling and air dehumidifying modules 22 assume control of the air humidity and the cooling ceiling 24 assumes control of the room temperature. The parts of the control circuits are: humidity sensor 27, humidity controller (hygrostat) 29, temperature sensor 26, temperature controller (thermostat) 28. The actuators in the closed loops are actuator valves in the cold water connectors in the embodiment illustrated as an example. Generally speaking, however, other known systems could be used, for example an adjustment of the temperatures or in the case of controlling the output of the module 22, varying the throughput of air through the mat packet, etc.. The separately acting humidity and temperature control circuits ensure that the room is maintained in a predefined state. This results in a very high quality in terms of the heat physiology to be obtained in the room 9 using simple means because the

advantages of the controlled air humidity in the room and the comfort-inducing, radiation-intensive heat absorption by the cooling panel are combined. As regards the control circuits, it would naturally also be possible to link their operation to one another, in which case the intended change of one controller is displayed to the other respective one, for example, e.g. in the form of a known disturbance feedforward, or the two controllers could be combined in a micro-computer, for example, and operate on the basis of a linked control strategy.

Example 8:

Fig. 12 illustrates a simplified aspect of the control technology, whereby the air cooling and air dehumidifying module 22 and the cooling ceiling, in this instance illustrated as a suspended cooling panel 25, are connected in series at the water end, and only a temperature control takes place by means of a sensor 26 and controller 28. Provided an exact load and power can be detected and the module 22 and suspended cooling panel 25 are dimensioned accordingly, the room temperature can be maintained exactly and the air humidity in the room kept within a range based on predefined threshold values. The power of the two components is correctly adapted and no condensation will occur on the cooling ceiling or on the suspended cooling panel, i.e. the entire system is intrinsically safe in this respect. Using circuit variant Y instead of variant X enables some of or the entire water flow between the cold water outlet 15 from the module 22 and the cold water inlet 14a into the suspended cooling panel 25 to be diverted. The advantage of using this variant is that it results in a controlled output distribution for the module 22 and the suspended cooling panel 25.

Example 9:

Another special solution which can be of advantage in many applications is illustrated in Fig. 13. The air cooling and air dehumidifying module 22 and the cooling ceiling, in this instance illustrated as a suspended cooling panel 25, are connected in series at the water end and the same water flow circulates through them, and the room temperature control system controls the water throughput, although the air dehumidification can still be controlled within limits because an actuator 30, for example a blind, influences the volume of air flowing through the mat packet. This variant is of practical advantage if only the maximum air humidity is limited and a maximum of cooling power is to be

produced by the cooling ceiling. Instead of the room air humidity, a humidity sensor on the cooling ceiling or on the suspended ceiling panel may be used as a signal transmitter.

Example 10:

Fig. 14 demonstrates one advantageous option for fitting air cooling and air dehumidifying modules 22 in conjunction with an opening cooling ceiling 24a, so that optimum use can be made of the ceiling cavity. The air flow 19 is drawn from the room in the uppermost region of the ceiling cavity. This is of advantage because warm, moist air has the lowest density and collects in the upper region of the room. Accordingly, the highest temperature and partial pressure differences act on the surface of the plastic capillary tube mats and are conducive to the cooling and dehumidification outputs. The incoming flow 23 of cooled and dehumidified air can be directed to the vicinity of the wall without causing draughts for the room users.

Example 11:

Fig. 15 to Fig. 17 illustrate advantageous possible ways in which an air cooling and air dehumidifying module 22 should be disposed so that it is effective in terms of heat engineering and in keeping with strict comfort criteria, together with a suspended cooling panel 25. As illustrated in Fig. 15, the air cooling and air dehumidifying module 22 draws the room air flow 19 at a distance of 50 to 100 mm below the suspended cooling panel 25, for example, so that the rising warm air is still not pre-cooled by the convective action of the cooling surface 25. The air flow 23 to be introduced back into the room passes out through the gap to the ceiling via the suspended cooling panel 25 so that the air flow into the room takes place outside of the area covered by the suspended ceiling panel. The main occupied areas, for example the workplaces at desks, are disposed underneath the suspended ceiling panel as a rule, where they will feel the heat and physiologically pleasant effect of the radiation cooling, and the lateral outflow of cold air does not have an unpleasant effect. The architectonic design of the suspended cooling panel may be such that outflow areas of cold air occur close to the wall. These air flows are then distributed in the floor region in the same way as with the tried and tested source air intake.

Fig. 16 shows the room air intake 19 in the top area of the room and the outlet from the air cooling and air dehumidifying module 22 which takes place at the side, e.g. by means of slotted nozzles, so that there is a blowing effect onto a passive suspended cooling panel 25a - using the Coandă effect. The surface 25a is therefore cooled as a result, causing a secondary effect of radiation cooling for the room.

Fig. 17 shows an arrangement of the air cooling and air dehumidifying module 22 directly above the suspended cooling panel 25 which is particularly easy to achieve from a construction point of view. The room air flow 19 is drawn from the upper area of the room and the conditioned air flow 23 is blown out directly above the suspended cooling panel 25, and the advantageous options of the other air directing system described in connection with Fig. 15 may be used.

Example 12:

Fig. 18 illustrates an additional feature to example 7 described in connection with Fig. 11, based on the advantageous option of the external air flow 19a and the way it is air-conditioned in an air cooling and air dehumidifying module 22. This enables a hygienically conditioned external air flow to be introduced, the size of which is defined depending on the number of room users or the volume of the room. It is of advantage that this air flow undergoes a change of temperature and humidity and thus largely enters the room as an incoming air flow 23 which has been adapted so as to achieve the comfortable room air state as far as is possible. In addition to this, another air cooling and air dehumidifying module 22 may operate on the basis of the known circulating air mode. Another improved aspect of the method incorporates a control of the external air volume flow 19a depending on the time of day, occupancy of the room the quality of the room air, for example.

List of reference numbers

- 1 Dimensionally stable mat packet formed by layers
- 2 Dimensionally stable mat packet formed by parallel winding
- 3 Dimensionally stable mat packet formed by parallel winding with open core region
- 4 Width of the mat packet
- 5 Height of the mat packet
- 6 Core region of the mat packet
- 7 Capillary tube of the plastic capillary tube mat
- 8 Distributor or collection pipe (so-called cores) of the plastic capillary tube mat
- 9 Room, the air of which is supplied with cooled and dehumidified air
- 9a External air flow (atmosphere) for filling the pressure chamber
- 10 Air flow through the mat packet
- 11 Housing
- 12 Pressure chamber (air at a pressure higher than in 9)
- 13 Condensate catchment container
- 14 Cold water intake for the air cooling and air dehumidifying module
- 14a Cold water intake for the cooling ceiling or suspended cooling panel
- 15 Cold water return from the air cooling and air dehumidifying module
- 15a Cold water return from the cooling ceiling or suspended cooling panel
- 16 Cold water connecting line
- 17 Fan for conveying air into the pressure chamber 12 or the core region 6
- 18 Blanking plate of the mat packet
- 18a Blanking plate of the mat packet with air intake orifice
- 18b Blanking plate of the mat packet with air intake orifice and integrated fittings for directing the air with low pressure losses
- 19 Air flow from the room for filling the pressure chamber
- 19a External air flow (atmosphere) for filling the pressure chamber
- 20 Length of the mat packet
- 21 Sealing body to prevent leakage flows of non-conditioned air
- 22 Air cooling and air dehumidifying module
- 23 Cooled and dehumidified incoming air flow to the room

- 24 Closed cooling ceiling
 - 24a Open cooling ceiling
- 25 Suspended cooling panel
 - 25a Suspended cooling panel with passive function
- 26 Temperature sensor in the room
- 27 Humidity sensor in the room
- 28 Controller for the cooling output as a function of room temperature (thermostat)
- 29 Controller for the dehumidification output as a function of the room humidity (hygrostat)
- 30 Actuator system for influencing the volume of air flowing through the mat packet

Claims

1. Air cooling and air dehumidifying module comprising plastic capillary tube mats for air-conditioning a room, comprising distributor and collection tubes with flexible capillary tubes extending in between, through which water is circulated at a selectable temperature,
characterised in that
the capillary tube mats are shaped to a compact, dimensionally stable packet (1; 2; 3) by forming layers (1), by winding (2) without an enlarged interior or by winding (3) with a defined core region (6) so as to obtain a body resembling a cuboid,
in that one or more mat packets (1; 2; 3) are disposed in a housing (11) with orifices so that a pressure chamber (12) is created, to which an air flow (19) to be treated is continuously fed by means of fans (17) from a room (9) to be air-conditioned, and
in that an air flow (10) occurs out of respectively into the pressure chamber (12) through the mat packet or packets (1; 2; 3) due to the pressure difference prevailing between the pressure chamber (12) and room (9).
2. Air cooling and air dehumidifying module as claimed in claim 1, **characterised in that**
the air circulation through the mat packet (1; 2; 3) is caused by a higher pressure in the pressure chamber (12) than the air pressure in the room (9), and the higher pressure occurs due to the fan (17) connected on the pressure side.
3. Air cooling and air dehumidifying module as claimed in claim 1, **characterised in that**
the height (5) of the cuboid body is at least twice its width (4).
4. Air cooling and air dehumidifying module as claimed in claims 1 to 3, **characterised in that**
sealing bodies (21) are used to seal the pressure chamber (12) in order to

prevent bypass flows of non-conditioned air.

5. Air cooling and air dehumidifying module as claimed in claims 1 to 4, **characterised in that** the orifices in the housing (11) are slots, holes or perforations, for example.
6. Air cooling and air dehumidifying module as claimed in the preceding claims, **characterised in that** a convective heat exchange takes place due to the contact between an air flow (10) and a capillary tube surface (7), and at a low water temperature in the capillary tube mats the air is also dried due to the formation of condensation water caused by a drop below the dew point at the capillary tube surface (7).
7. Air cooling and air dehumidifying module for air-conditioning a room as claimed in the preceding claims, **characterised in that** the permanent dimensional stability of the mat packet (1; 2; 3) is achieved by commercially available plastic binders or by using memory effect, for example by a thermal pre-treatment.
8. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** several mat packets (1; 2; 3) are connected in series one after the other or in parallel in the same air flow (10) to improve the efficiency of the heat exchanger and dehumidification, and the water flow is directed in counter-flow by providing a cold water inlet (14), a cold water connecting pipe (16) and a cold water outlet (15).
9. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the mat packet (3) with a defined core region (6) is positioned in the housing (11) so that the mat-free core region (6) assumes the function of the pressure chamber (12) and is filled with room air (19) by means of fans (17), and the air

flow (10) distributed to several sides in the room (9) makes contact with the capillary tube surface (7) so that the thermodynamically conducive operating characteristic, namely the counter-flow, is achieved with an outwardly lying water inlet (14) and an inwardly lying water outlet (15).

10. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 1 to 4, **characterised in that** the pressure chamber (12), which may be identical to the core region (6), has integrated fittings for distributing the air, which ensure an air discharge into the room (9) that is uniform or selectively directed depending on the usage conditions.
11. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 1 to 5, **characterised in that** the air intake of the room air (19) can be flexibly designed depending on the disposition of the module in the room, which is preferably achieved by providing a plug-in flange and/or using roller fans with rotatable housings.
12. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 1 to 6, **characterised in that** the housing (11) is shaped to form special air passage elements on the surfaces of the air passage into the room or is connected to such by known means, and perforated plate arrangements, slotted passages or adjustable slat plates constitute preferred solutions in this respect.
13. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the mat packets (3) with a defined core region (6) which may simultaneously form the pressure chamber can be fitted horizontally.
14. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that**

a housing (11) can be dispensed with if using the mat packets (3) with a defined core region (6) and the core region is closed by means of a closed blanking plate (18) and by a blanking plate (18a) with an air intake orifice lying opposite.

15. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the pressure chamber (12) is filled with room air flows (19) by means of several fans (17).
16. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** shaped pieces are fitted between the fan (17) / fans (17) and the pressure chamber (12) in order to direct and deflect the air flow.
17. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the mat packet (1; 2; 3) is enclosed by a perforated foil, the perforations of which constitute the air passage orifices.
18. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** a constant, automatically controllable or controllable external air flow (19a) is fed to the pressure chamber (12).
19. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the air circulation to the room (9) is designed so that air is blown onto surfaces, preferably windows or passive suspended cooling panels (15a), so that their surface temperature is reduced.
20. Air cooling and air dehumidifying module for air-conditioning a room as claimed in the preceding claim, **characterised in that**

the advantages of the Coandă effect are used.

21. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims 15, **characterised in that** one or more air filters and/or air humidifiers are integrated in the air path through the air cooling and air dehumidifying module.
22. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 1 to 16, **characterised in that** the power regulation of the air cooling and air dehumidifier module (22) takes place on the basis of a variable water temperature, a variable water flow and/or a variable flow volume of air through the mat packet (1; 2; 3).
23. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the air circulation through the mat packet (1; 2; 3) is caused by a lower pressure in the pressure chamber (12) than the air pressure in the room (9), and this occurs due to the fact that the fan (17) is connected at the suction end.
24. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the mat packet / the mat packets (1; 2; 3) is / are disposed in the housing (11) so that the air circulation through the mat packet / mat packets (1; 2; 3) is caused by density differences between the cooled air and the room air at reduced power.
25. Air cooling and air dehumidifying module for air-conditioning a room as claimed in one of the preceding claims, **characterised in that** the module (22) is also able to assume a heating function by using water temperatures above the room air temperature.
26. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in claims 1 to 24, **characterised in that**

the air cooling and air dehumidifying module (22), irrespective of its spatial location, and the cooling ceiling, irrespective of its construction type (24; 24a; 25), constitute a control unit for air-conditioning the room (9), and the power of the air cooling and air dehumidifying module is controlled so that the desired value of the room air humidity is preserved and the power of the cooling ceiling is controlled so that the desired value of the room temperature is guaranteed.

27. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in claim 25, **characterised in that** the air cooling and air dehumidifying module (22) and the cooling ceiling (24; 24a; 25) is supplied by cold water flows (14; 14a) that are different in terms of their initial temperature with a view to gaining the advantage of a low exergy during operation, and the water flow with the lower temperature is circulated through the air cooling and dehumidifying module (22).
28. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in claim 25 or 26, **characterised in that** an open cooling ceiling (24a) or a suspended cooling panel (25) is used and the air cooling and dehumidifying module (22) draws the room air (19) from the ceiling gap.
29. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 27, **characterised in that** the air cooling and dehumidifying module (22) and the cooling ceiling (24; 24a) or the suspended cooling panel (25) are structurally connected to one another and/or form a structural unit.
30. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 27, **characterised in that** the room temperature and/or the room air humidity is controlled for a defined room zone or for a group of rooms.

31. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 29, **characterised in that** the control variables comprising room temperature and room air humidity are arithmetic or weighted mean values derived from the signals of several measuring sensors.
32. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 30, **characterised in that** adaptation of the power of the air cooling and dehumidifying module (22) and/or the cooling ceiling (24; 24a) and/or the suspended cooling panel (25) is achieved on the basis of a time control system.
33. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 31, **characterised in that** the air cooling and dehumidifying module (22) and/or the cooling ceiling (24; 24a) and/or the suspended cooling panel (25) is operated as a function of predefined temperature and/or humidity threshold values which are exceeded or below which there is a drop.
34. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 32, **characterised in that** the operation and power control of the air cooling and dehumidifying module (22) and/or the cooling ceiling (24; 24a) and/or the suspended cooling panel (25) are based on the premise of maintaining the room temperature.
35. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 33, **characterised in that** the dehumidifying power of the air cooling and dehumidifying module (22) is automatically regulated or controlled as a function of the signal of one or more humidity sensors and/or temperature sensors which are installed in conjunction with the cooling ceiling (24; 24a) and/or the suspended cooling panel (25) so that condensation is prevented on the cooling ceiling.

36. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 34, **characterised in that** the operation and power regulation of the air cooling and dehumidifying module (22) and/or the cooling ceiling (24; 24a) and/or the suspended cooling panel (25) take place as a function of the target function of achieving minimum exergy at optimum room air conditioning and/or thermal comfort.
37. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 35, **characterised in that** the cooling ceiling (24;24a) and/or the suspended cooling panel (25) is connected downstream of the air cooling and dehumidifying module (22) at the water end, and the cold water return (15) from the air cooling and air dehumidifying module corresponds to the cold water intake (14a) for the cooling ceiling or for the suspended cooling panel.
38. Method of using an air cooling and air dehumidifying module for air-conditioning a room as claimed in one of claims 25 to 36, **characterised in that** the air cooling and dehumidifying module (22) operates in combination with other room cooling surfaces, the output of which can be automatically regulated and/or controlled, for example flat room dividers or wall surfaces, in addition to or instead of cooling ceilings.