

Air conditioning via multi-phase plate heat exchanger

Introduction

Air conditioning consumes a high proportion of the global electricity supply and thus also contributes to the Earth's CO₂ balance. Energy can be saved by heat recirculation, especially via heat exchangers. Heat is not only stored or transported in the heat capacity of the substances concerned, but even more so in the enthalpy of the water vapor involved. Heat recovery can only take place efficiently if cooling and heating, condensation and evaporation take place simultaneously and at the same place. This requires a new concept for the heat exchanger principle, which will be described here.

Description of the prior art

Air conditioning is preferably carried out in summer by electrically operated refrigeration machines or in winter by burning flammable substances. To achieve a comfortable climate, water vapor must normally be separated from the air by condensation or added by evaporation. In extreme cases, the energy required for this is many times greater than is required to cool or heat the vapor-free air over the same temperature interval. The condensation water is discarded instead of being used for evaporation cooling.

So-called controlled ventilation should help to save energy by using air-air heat exchangers. Although in winter it is possible to bring the outside temperature almost to the inside temperature, this heated fresh air is extremely dry and must be humidified afterwards with an energy supply. In summer the problem is even worse: Since the enthalpy difference between moist hot outdoor air and cool dry indoor air is much greater than the enthalpy difference between dry indoor air and the same air at outdoor

temperature, such a heat exchange can only ever make a very small contribution to reducing the required cooling capacity.

Patent specification A192/2015 therefore describes an air-air heat exchanger where the condensate formed during cooling is fed from the fresh air to the exhaust air in order to evaporate into it and thereby compensate for the heat of condensation released as heat of evaporation.

However, real cooling of the air below the temperature prevailing in the room to be air-conditioned, which would be necessary to eliminate other heat inputs such as solar radiation or computer heat, cannot take place. Therefore, this concept still requires the use of an active secondary cooling system, which usually has to bear more than half of the total cooling load.

An additional problem arises from the fact that constant humidification of the heat exchanger surfaces can lead to bacterial or other microbial growth, which could subsequently lead to clogging or even to the transmission of diseases.

Problem to be solved

In principle, it should be possible to achieve the entire cooling capacity by evaporative cooling in summer with a suitable heat exchanger, because the enthalpy difference between dry indoor air and air saturated with steam at outdoor temperature must always be greater than the enthalpy difference between moist hot outdoor air and cool dry indoor air. In practice, however, this comparison is not quite correct for entropy reasons.

After all, in many climatic situations, pure evaporation cooling is possible if only enough water is supplied to the heat exchanger on the exhaust side. In cases where the humidity is too high, the air can be reduced by hygroscopic solution.

Conversely, for the heating of cold humid air in the cold season, this air can be heated by hygroscopic drying of the same.

The objects of the invention are therefore as follows:

- Air conditioning of rooms by means of evaporation cooling or heating by hygroscopic air drying for different climatic conditions of the external environment
- Hygienic conditions in the heat exchanger
- Control of the humidity in the rooms to be air-conditioned by a hygroscopic solution or water evaporation
- Regeneration of the hygroscopic solution after it has absorbed water, possibly leading to crystallization processes that must not interfere with the entire process, using the same device
- The highest possible compact design for the whole device

Achievement of the stated objects and sub-tasks and the results to be expected therefrom

The object of air conditioning rooms by pure evaporation cooling or heating by hygroscopic air drying is accomplished by an innovative multi-phase plate heat exchanger.

A multi-phase plate heat exchanger is a plate heat exchanger for two gaseous media of different temperature and different vapor content, each of which is moved in countercurrent or parallel flow by an adjustable blower, wherein the active heat transfer surface between the media concerned is wetted on one or both surfaces by one or two different slow flowing liquids which interact directly with the respective media, so that evaporation or condensation and, due to the resulting changes in concentration in the liquids, crystallization or solution of crystals can also take place, wherein these liquids are pumped from the outside to their specific inlet positions between the heat exchanger plates and move from there through the plate

heat exchanger as a more or less thick liquid film following the forces of capillary action, air flow, turbulence, gravitation or the constraining forces of special plate formations, so that associated media and liquids often do not flow in the same direction.

In order to operate such a multi-phase heat exchanger successfully, the additional object is to introduce the mentioned liquids drop by drop into the gaps of the heat exchanger, wherein the quantity introduced per gap should not vary greatly. There are three methods to solve this problem:

- To allow the liquid supply from a storage tank to the inlet positions between the heat exchanger plates to take place in such a way that the supply line after the pump spreads out into a bundle of capillary tubes or hoses which flow into the heat exchanger at the corresponding destinations.
- To allow the liquid supply from a storage tank to the inlet positions between the heat exchanger plates so that the supply line after the pump leads to a common connecting channel between the heat exchanger plates formed of congruently corresponding openings through these plates, wherein in each plate gap into which liquid is to be introduced a throttle is provided for the dropwise liquid passage from the connecting channel into the gap.
- To spray the liquid from nozzles in front of the plate gap entrances, wherein the resulting drops should not be too small to keep interaction with the air at a low level prior to the impact of the drops on the surfaces to be wetted. This arrangement is particularly recommended for large systems.

Experiments have shown that the supply of liquid through capillaries is considerably more complicated and expensive than the alternative of a

common connecting channel across all plates, but that the even distribution of the liquid across all plates is much more accurate, which improves the efficiency of the system considerably.

Experiments have also shown that precise dosing of the liquids to be supplied by capillaries or nozzles alone is very inaccurate, because the smallest impurities can change the flow resistance and thus also the flow rate at the same pump strength. It is therefore better to let the pumps operate in short shocks, wherein the duration of the shock and the time interval between the shocks can be varied according to the measured data from suitable sensors which determine the heat transfer as well as the evaporation and condensation capacity in the heat exchanger.

As soon as the mentioned liquids have been fed to the plate surfaces in the correct quantity, the next task is to wet these plate surfaces evenly.

This object is achieved in that the surfaces of the active heat transfer surfaces promote the even distribution of the liquid film or the local retention of crystals or their further transport by grooves, finely porous surfaces, grinding marks, scratches and/or fiber coating, as well as coatings by hydrophilic materials or also by a combination of several such measures. Experimentally, a coating of the heat transfer surfaces with super-hydrophilic TiO_2 nanocrystals has also proven to be very practical.

In order to achieve the object of controlling the humidity in the rooms to be air-conditioned with a hygroscopic solution or evaporating water, there is the possibility of an isenthalpic transition on the one hand and additional heating or cooling may be necessary on the other hand. An isenthalpic transition can be achieved in the multi-phase heat exchanger according to the invention by introducing the same air flow into the primary side and the secondary side of said heat exchanger so that these two flows flow parallel and in the same direction, wherein the same liquid is used to wet the heat exchanger surfaces in both flows. If this liquid is water, the air flow is cooled during the

isenthalpic transition while it simultaneously saturates with water vapor. If this liquid is a hygroscopic solution, however, the air flow is heated during the isenthalpic transition. Thus, in the first case a cooling effect and in the second case a heating effect can be achieved.

If, on the other hand, the air flow is to be cooled by hygroscopic solution during dehumidification, additional cooling of the heat exchanger by another medium can be helpful. The multi-phase heat exchanger according to the invention can also be used for this purpose, wherein on the primary side the air to be dehumidified is introduced together with a hygroscopic solution wetting the heat exchanger surface in countercurrent and on the secondary side the medium to be cooled, which can flow in direct current or in countercurrent, depending on requirements, and which can be gaseous or liquid.

Conversely, if an air stream is to become warmer when it is humidified, this occurs as an object, for example, when the hygroscopic solution is regenerated after it has absorbed water. In this case, heating is necessary, which can also be carried out in the multi-phase heat exchanger if the secondary medium can supply heat.

Both objects can be achieved simultaneously if the inlets for media or liquids or individual sections of the heat exchanger itself are in heat-conducting contact with separate temperature control media or an electrical heater in the multi-phase plate heat exchanger described, which can heat or cool these areas.

The installation of an external temperature control facility and its space requirements underline the importance of the above-mentioned object of finding the most compact design possible for the entire unit. This object is achieved by a combination of a multi-phase heat exchanger with two or more of the plate heat exchangers for heating or cooling purposes, wherein

this combination consists of a single plate pack and each of the individual partial heat exchangers form congruent areas on the plates of this pack.

The object of guaranteeing hygienic conditions in the heat exchanger and limiting the humidity in the rooms to be air-conditioned by a hygroscopic solution is jointly achieved in such a way that the liquids with which the active surfaces in the multi-phase plate heat exchanger are wetted may contain water or other solvents as well as hygroscopic salts, refrigerants, disinfectants or wetting agents. The already mentioned coating of the heat transfer surfaces with TiO_2 nano-crystals has an additional positive effect in this context. Due to the known photocatalytic properties of TiO_2 , organic materials or microbes that would normally adhere to the surface are chemically decomposed when the heat exchanger surfaces are illuminated and their residues are flushed away from the liquid. For this purpose, either the multi-phase heat exchangers must be made of transparent plastic or lighting must be provided that shines into the heat exchanger plate gaps.

In summary, the object of air conditioning rooms by pure evaporation cooling and limiting the humidity in the rooms to be air-conditioned by a hygroscopic solution in this case is achieved in such a way that in a multi-phase plate heat exchanger the primary medium is the hot and humid outside air of an inhabited room and the secondary medium is the consumed but relatively dry and cool air of the inhabited room, which flows in countercurrent to the primary medium, and that the inner surfaces of the plate gaps for the primary medium are wetted with hygroscopic solution, wherein this liquid and the air flow in opposite directions while the inner surfaces of the plate gaps for the secondary medium are wetted with water which can flow in any direction. This provides fresh air with an approximate room temperature but much lower relative humidity than the room humidity. If the room is to be cooled, the fresh air is dried in this way, followed by isenthalpic humidification with cooling effect, whereby a temperature can be reached that is significantly below the dew point of the room air.

The object of heating a room by hygroscopic air drying is achieved in such a way that in a multi-phase plate heat exchanger the primary medium is the cold outside air of an inhabited room and the secondary medium is the consumed but relatively humid and warm air of the inhabited room, which flows in countercurrent to the primary medium, and in that in this case the inner surfaces of the plate gaps for the secondary medium are wetted with hygroscopic solution, wherein this liquid and the air flow in opposite directions while the inner surfaces of the plate gaps for the primary medium are wetted with water which can flow in any direction. This provides fresh air with an approximate room temperature but much higher relative humidity than the room humidity. If this moist fresh air is now subjected to isenthalpic drying until the desired room humidity is reached, a temperature significantly above the prevailing room temperature is reached. It should be noted that suitable frost protection must be provided for humidifying the active surfaces at outside temperatures below zero degrees for the water vapor saturation of the outside air in the multi-phase heat exchanger. In the low-temperature range, antifreeze with low intrinsic steam pressure can be added instead of pure water.

The secondary condition of the object of air-conditioning rooms by evaporative cooling or heating by hygroscopic air drying was to achieve this object for different climatic conditions of the external environment. This is achieved according to the invention by combining several of these multi-phase heat exchangers into one system. For cooling in a room with dry air, it may make sense to humidify the exhaust air first in a multi-phase heat exchanger for isenthalpic evaporation before carrying out the cooling process described above. The same applies to heating a relatively dry room. Here too, it may make sense to humidify the exhaust air first in a multi-phase heat exchanger for isenthalpic evaporation.

Conversely, in a humid tropical climate, it is advantageous to pre-dry the fresh air in a multi-phase heat exchanger for isenthalpic drying before entering the cooling process described above.

The possibility of heating or cooling a room without visible energy supply is by no means a perpetuum mobile. A hygroscopic salt solution is a highly efficient energy source. For example, a concentrated LiCl solution can absorb 10 to 15 times its own volume of water from moist air. The resulting heat of condensation which can be released by one liter of concentrated LiCl solution is thus approximately as large as the amount of heat which is produced when one liter of heating oil is burned. According to this, a concentrated hygroscopic solution can also serve as a heat store, which can store potential energy for as long as desired without thermal insulation.

The object of regenerating the hygroscopic solution by a similar device after this solution has absorbed water and thus become diluted and ineffective is achieved by a multi-phase plate heat exchanger, where the primary medium is hot and humid outside air and where the inner surfaces of the plate gaps for the primary medium are wetted with preheated, diluted and little hygroscopic solution in countercurrent to the primary medium, and where the secondary medium which flows in countercurrent to the primary medium is the same air which, after the primary passage through the heat exchanger, is additionally heated and almost saturated with steam, whereby condensation forms on the inner surfaces of the plate gaps for the secondary medium during cooling thereof, which, when cooled in direct current with the secondary medium, leaves the heat exchanger.

Since it cannot be excluded that salt crystals may form during the described drying process for the regeneration of the hygroscopic solution which, if they are transported away from the heat exchanger by the flow, could possibly lead to blockages of the system, it is desirable as an additional task object that such crystals remain at their place of origin, where they are then dissolved again by condensation water in the next cooling phase, provided that this takes place in the same unit. This can be achieved when the multi-phase plate heat exchanger is positioned so that its plates are horizontal and there are grooves or waves transverse to the flow direction in which these crystals are deposited by gravity.

Description of the drawings and relevance of the numbers

Figs. 1a to 1d show four different ways of using a multi-phase plate heat exchanger, namely:

Fig 1a shows a schematic representation of a single-stage cooling unit with multi-phase plate heat exchanger and hygroscopic air drying.

Fig. 1b shows solution regeneration with the same device.

Fig. 1c shows isenthalpic humidification and cooling using a multi-phase plate heat exchanger.

Fig. 1d shows isenthalpic air drying and heating using a multi-phase plate heat exchanger.

Figs. 2a and 2b show sections across the plates with the guidance of primary and secondary media and the liquid layers wetting the plates.

In this case, Fig. 2a shows a heat exchanger with vertical plates and a liquid supply line through capillaries and Fig. 2b shows a liquid supply through distribution channels across horizontal plates.

Fig. 3 shows the diagram of a three-stage arrangement of a cooling unit with a multi-phase plate heat exchanger and two isenthalpic humidifiers.

Fig. 4 shows the diagram of a three-stage arrangement of a heater with a multi-phase plate heat exchanger, an isenthalpic humidifier and an isenthalpic air dryer.

Fig. 5 shows a diagram in which the steam supply for solution regeneration of Fig. 1b is achieved by an air humidifier in the form of a multi-phase plate heat exchanger.

The numbers in the illustrations mean:

A	Surrounding area
B	Air-conditioned room
1	Gaseous primary medium
1a	Plate gaps for the primary medium
2	Gaseous secondary medium
2a	Plate gaps for the secondary medium
3	Liquid for wetting the inner walls of the primary medium heat exchanger gaps
4	Liquid for wetting the inner walls of the secondary medium heat exchanger gaps
5	Capillaries for the supply of primary medium liquid
6	Pipe for the discharge of primary medium liquid
7	Capillaries for the supply of secondary medium liquid
8	Pipe for the discharge of secondary medium liquid
9	Connecting channel for supplying liquid to the primary medium
9a	Very small opening in the connection channel (9) or at the end of a capillary (5) with throttling effect
10	Connecting channel for the supply of liquid to the secondary medium
10a	Very small opening in the connection channel (10) or at the end of a capillary (7) with throttling effect
11	Solution pump for the primary side
12	Solution pump for the secondary side
13	Heat exchanger plates
13a	Active area of the heat exchanger,(= partition wall between primary medium and secondary medium)

14	Multi-phase plate heat exchanger
14a	Primary side of the multi-phase plate heat exchanger
14b	Secondary side of the multi-phase plate heat exchanger
14c	Humidifier, in the form of a multi-phase plate heat exchanger
14d	Air dryer, in the form of a multi-phase plate heat exchanger
15	Fresh air in the vicinity of a room to be cooled
15a	Heated fresh air saturated with steam
16	Exhaust air from an air-conditioned room
17a	Concentrated hygroscopic solution
17b	Diluted hygroscopic solution
17c	Heated diluted hygroscopic solution
18	Water
19	Condensing water
20	Hot steam

Description of the illustrations

Fig. 1a shows how the multi-phase plate heat exchanger according to the invention is used for a ventilation system with cooling function in a warm, humid climate. The multi-phase plate heat exchanger -14-, which in reality usually consists of many chambers formed by plates, is conceptually represented by two adjacent chambers -14a, 14b-, separated by an active surface -13a-, with the upper of the two chambers -14a- symbolizing the heat exchanger plate gaps of the primary side and the lower -14b- symbolizing the heat exchanger plate gaps of the secondary side. Thick solid lines represent the heat exchanger, thin solid lines represent the air flows, dotted lines the wetting liquids. On the primary side -14a-, hot moist fresh air -15- comes into contact with hygroscopic solution -17a, 17b- in the heat exchanger. In this case, water vapor condenses in the solution -17a- and the resulting heat is released through the active surface -13a- to the secondary

side -14b- of the heat exchanger. The fresh air -15-, cooled to room air temperature and dehumidified, is fed into the room to be cooled. The hygroscopic solution -17b- diluted by water condensation leaves the heat exchanger -14- and is then fed to regeneration, which is described in Fig. 1b. On the secondary side -14b-, cool dry exhaust air -16- from the room to be cooled is brought into contact with water -18-, wherein heat from the condensation and heat from the cooling of the fresh air -15- are simultaneously available from the primary side -14a- for the evaporation of a part of the water -18-. This heat is thus extracted from the primary side -14a-, which is why a cooling effect occurs in the fresh air. The remaining water -18- is only slightly heated and runs back into a storage tank.

Fig. 1b shows as a further application example of the multi-phase plate heat exchanger -14- the regeneration of the hygroscopic solution -17b- diluted by the cooling process in Fig. 1a and thus unusable. This corresponds to a particularly energy-efficient form of water desalination, for which there are also a large number of applications. On the primary side -14a-, fresh air -15- is brought into contact with heated diluted hygroscopic solution -17c- - wherein the heating is not shown - whose temperature must be so high that its vapor pressure is above the vapor pressure of the fresh air -15-. The fresh air -15- then absorbs additional water vapor until it is saturated. Since this fresh air -15- at the same time flows against the heated solution -17c- however, it itself becomes warmer and can absorb additional water vapor and eventually becomes a hot, almost steam-saturated air -15c-. As a result of this process, the solution -17b- cools down as its concentration increases simultaneously, leaving the heat exchanger -14- as a concentrated cool solution -17a- and can be used again for a cooling process. The secondary side -14b- serves for the energy recovery of the condensation heat which arises because the hot air -15c- saturated with steam is directed to the secondary side of the heat exchanger -14b-, where heat is extracted therefrom from the primary side -14a-, whereby it cools down and the resulting excess steam -19- condenses on the active surface -13a- between

the primary side -14a- and the secondary side -14b- and thus provides the heat of condensation for the evaporation of solution water on the primary side -14a-. As a rule, however, the steam content of the humidified fresh air -15-, after leaving the primary side -14a-, will not be sufficient to maintain the described energy recovery process permanently. A small amount of hot steam -20- must be supplied to the air -15- at the point where it changes from the primary side -14a- to the secondary side -14b-.

Fig. 1c shows the isenthalpic humidification and cooling of fresh air -15- by means of a humidifier-14c-, in the form of a multi-phase plate heat exchanger -14-. The incoming fresh air -15- is first divided into 2 streams, which are directed parallel to each other into the primary side -14a- and secondary side -14b- of an air humidifier -14c-, in the form of a multi-phase plate heat exchanger -14-, where it is brought into contact with water -18-, which wets the active surfaces -13a- and may move in any direction. In this case, water -18- evaporates, gradually saturating the fresh air -15- with moisture and cooling it.

Fig. 1d shows the isenthalpic drying and heating of fresh air -15- by means of an air dryer -14d-, in the form of a multi-phase plate heat exchanger -14-. The incoming fresh air -15- is first divided into 2 streams which are directed parallel to each other into the primary side -14a- and secondary side -14b- of an air dryer -14d-, in the form of a multi-phase plate heat exchanger 14, where it is brought into contact with hygroscopic solution -17a, 17b- which wets the active surfaces -13a- and is to move advantageously in countercurrent to the fresh air -15-. Water vapor from the moist fresh air -15- condenses in the hygroscopic solution -17a, 17b- and thus gradually dries the fresh air -15- and heats it in this process.

Fig. 2a shows a schematic section across the plates of a multi-phase plate

heat exchanger with liquid supply line through the pumps -11, 12- and the capillaries -5,7- acting as throttles in a case where the liquid path is mainly determined by gravity, i.e. a situation, where vertically positioned plates are recommended, since in each heat exchanger plate gap - 1a, 1b- both adjacent surfaces can be wetted with liquids -3, 4- without any problems, wherein the guidance of primary -1- and secondary medium -2- as well as the liquid layers -13- wetting the plates -3, 4- is shown. In addition, a pipe system -6, 8- similar to the capillaries -5, 7- for draining off the residual liquid can be seen. This residual liquid, whether water -18- or diluted hygroscopic solution -17b-, can either be moved by gravity to a storage tank or by a pump to other system tasks. It should be noted that this liquid inlet and outlet works not only for vertical heat exchanger plates but also for plates with any inclination, if the plate surfaces are designed or coated in such a way that their wetting with liquid is always guaranteed. This is particularly successful when the plate surfaces are made of fine-pored or fine-fibrous material.

Fig. 2b shows a schematic section across the plates of a horizontal multi-phase plate heat exchanger with liquid supply line through pumps -11, 12- and connecting channels -9, 10- across the heat exchanger plates -13-, wherein small openings -9a, 10a- with throttling function allow a dropwise supply of the liquid layers -3, 4- at the openings through the gaps of the respective corresponding medium -1, 2-. Here, too, a pipe system -6, 8- for draining off the residual liquid was shown in the drawing. However, a liquid discharge analogous to the liquid supply line through the connecting channels -9, 10- across the heat exchanger plates -13- shown here would also lead to the desired result. This residual liquid, whether water -18- or diluted hygroscopic solution -17b-, can either be moved by gravity to a storage tank or by a pump to other system tasks. This type of liquid supply and drainage can also work for plates of any inclination if wetting with liquid is always guaranteed.

Fig. 3 shows the diagram of a three-stage cooling system between the hot external ambient air -A- and the air in the room -B- to be cooled, consisting of a multi-phase plate heat exchanger -14- and two isenthalpic humidifiers -14c- and -14c', which have a design like that shown in Fig. 1c. The fresh air -15-, coming from the environment -A-, is dehumidified in the primary side -14a- in the multi-phase plate heat exchanger -14- by the hygroscopic solution -17a, 17b- wetting the active surface -13a-, which moves in the opposite direction to the air -15-. The resulting heat is conducted through the active area -13a- of the multi-phase plate heat exchanger -14- to the secondary side -14b-, where exhaust air -16- flows from the room to be cooled -B- towards the external environment -A-. Since the active area -13a- on the secondary side -14b- is wetted with water -18-, which is offered in excess, exactly as much water -18- is evaporated into the exhaust air -16- on the secondary side -14b- as corresponds to the heat supply from the primary side -14a-. This exhaust air flowing into the multi-phase plate heat exchangers -14- is already colder and more humid than the air in the air-conditioned room -B-, as it has already passed through the isenthalpic humidifier -14c-, where it has cooled down to the dew point of the air-conditioned room -B- by absorbing water -18- and is saturated with moisture. Nevertheless, this saturated exhaust air -16- can continue to absorb water vapor in the multi-phase plate heat exchanger -14-, since it is heated itself by absorbing the heat generated by the fresh air dehumidification process. On the other hand, the fact that exhaust air -16- flows into the multi-phase plate heat exchanger -14- with the temperature of the dew point of the air-conditioned room -B- allows the now dried fresh air -14- to also have a temperature close to this dew point when leaving the multi-phase plate heat exchanger -14-. This cold dry fresh air -15- is now directed to the isenthalpic humidifier -14c'-, where it is brought to a temperature significantly below the dew point of this air-conditioned room -B- by remoistening with water -18-.

Fig. 4 shows the diagram of a three-stage heating system between the external cold ambient air -A- and the air in the room -B- to be heated,

consisting of a multi-phase plate heat exchanger -14-, an isenthalpic humidifier -14c- and an isenthalpic air dryer -14d-, which have designs like those shown in Fig. 1c and Fig. 1d. The fresh air -15- coming from -A- is humidified in the primary side -14a- in the multi-phase plate heat exchanger -14- by the water -18- wetting the active surface -13a-, which is offered in excess. The heat required for this purpose is drawn through the active area -13a- of the multi-phase plate heat exchanger -14- from the secondary side -14b-, where exhaust air -16- flows from the room -B- to be heated towards the external environment -A-. Since the active surface -13a- on the secondary side -14b- is wetted with hygroscopic solution -17a, 17b- which moves in the opposite direction to the exhaust air -16-, exactly as much water -18- is evaporated into the fresh air -15- on the primary side -14a- as corresponds to the heat supply from the secondary side -14b-. This exhaust air -16- flowing into the multi-phase plate heat exchanger -14- is already slightly colder and wetter than the air in the air-conditioned room -B-, since it has already passed the isenthalpic humidifier -14c-, where it has been humidified to an optimum value by absorbing water -18-, which can be calculated for each individual case from the enthalpy data of humid air. In practice, automatic control by a programmable chip in combination with appropriate temperature and humidity sensors and flow meters is recommended. In this case, the control functions via the amount of water -18- supplied in relation to the air flow -16-. The advantage of this humidification in the isenthalpic humidifier -14c- is that enough steam is then available to allow complete humidification of the fresh air -15- by subsequent condensation in hygroscopic solution -17a, 17b- in the multi-phase plate heat exchanger -14-. The fresh air -15- then leaves the multi-phase plate heat exchanger -14- saturated with steam and at a temperature not far below that prevailing in room -B- and is directed to the isenthalpic air dryer -14d-, where it is dried by the hygroscopic solution -17a, 17b- with simultaneous heating and can then be used to heat the air-conditioned room -B-.

Fig.5 shows a diagram in which the steam supply for solution regeneration of Fig. 1b is achieved by an air humidifier -14c- which is designed in analogy to Fig. 1c, but without isenthalpy because hot water is supplied. There are many state-of-the-art steam generators.

However, a humidifier -14c-, like the multi-phase plate heat exchanger -14- described here, proves to be particularly effective for the task of regenerating hygroscopic solution, since it only consumes exactly the amount of steam needed for the process minus the reusable condensation heat. Drying of the hygroscopic solution -17c, 17a- wetting the active surface -13a- is possible on the primary side -14a- of the multi-phase plate heat exchanger -14- in such a way that water vapor -19- condensing on its secondary side -14b- supplies the necessary process heat. Since the hot hygroscopic solution -17c- to be evaporated has a vapor pressure below the vapor pressure of saturated fresh air -15- which has the same temperature, this fresh air -15- cannot be brought to a humidity of 100% in the multi-phase plate heat exchanger -14- which would be necessary for condensation at this temperature. Therefore, this hot and very humid fresh air -15- coming from the primary side -14a- of the multi-phase plate heat exchanger -14- is directed to a humidifier -14c-, where it is brought into contact with hot water -18a- in countercurrent. In this case, the fresh air -15- is heated further and saturated with steam. As soon as it is then fed back into the multi-phase plate heat exchanger -14- on its secondary side - 14b-, just as much water vapor condenses as is necessary to maintain the drying process on the primary side -14a- of the multi-phase plate heat exchanger -14-. To optimize the overall process, it is necessary to select the temperature of the hot water -18a- in the humidifier -14c- so that the temperature of the fresh air -15- leaving the multi-phase plate heat exchanger -14- is as close as possible to the temperature it had before the entire process.

CLAIMS:

1. Multi-phase plate heat exchanger (14) for 2 or more gaseous media (1, 2) which are moved in countercurrent or parallel flow by one or more controllable blowers, having different temperatures and different vapor content, characterized in that the active surfaces (13a) for heat transfer between the media (1, 2) concerned are wetted on one or both surfaces by one or two different slowly flowing liquids (3, 4) which interact directly with the respective media (1, 2), so that evaporation or condensation and, due to the resulting concentration changes in the liquids, also crystallization or solution of crystals can take place, wherein these liquids (3, 4) are pumped from the outside to their specific inlet positions (9a, 10a) between the heat exchanger plates (13) and move from there as a wetting liquid film along the active surfaces (13a) through the plate heat exchanger (14), wherein related media (1, 2) and liquids (3, 4) can flow in parallel or in countercurrent to one another.

2. Multi-phase plate heat exchanger according to claim 1, characterized in that the liquid supply from a storage tank to the small openings (9a, 10a), which serve as inlet positions between the heat exchanger plates (13), takes place such that the supply line after the pump (11, 12) fans out into a bundle of capillaries (5, 7) in pipe or tubular form which open at the corresponding small openings (9a, 10a) into the heat exchanger.

3. Multi-phase plate heat exchanger according to claim 1, characterized in that the liquid supply from a storage tank to the small openings (9a, 10a) which serve as liquid inputs between the heat exchanger plates (13) takes place such that the supply line after the pump (11, 12) leads to a common connecting channel (9,10) between the heat exchanger plates (13) formed of congruently corresponding apertures

through these plates (13), wherein in each plate gap (1a, 1b), into which liquid is to be introduced, a throttle (9a, 10a) is provided for the dropwise liquid passage from the connecting channel (9, 10) into the gap (1a, 2a).

4. Multi-phase plate heat exchanger according to one of the preceding claims, characterized in that the inlets for media (1, 2) or liquids (3, 4) or individual sections of the heat exchanger (14) themselves are in heat-conducting contact with separate temperature control media or an electrical heater which can heat or cool these areas.
5. Combination of two or more of the multi-phase plate heat exchangers with other plate heat exchangers according to one of the preceding claims, characterized in that this combination consists of a single plate pack and the individual partial heat exchangers each form congruent areas on the plates of this pack.
6. Multi-phase heat exchanger or combination of heat exchangers according to one of the preceding claims, characterized in that said liquids (3, 4) may contain water or other solvents as well as hygroscopic salts, refrigerants, disinfectants or wetting agents.
7. Heat exchanger or combination of heat exchangers according to one of the preceding claims, characterized in that the surfaces (3, 4) of the active surfaces (13a) for heat transfer enable the uniform distribution of the liquid film (3, 4) or the local retention of crystals or their further transport mechanically by grooves, finely porous surfaces, grinding marks, scratches and/or fiber coating, as well as by hydrophilic materials and coatings or also by a combination of several such measures.

8. Multi-phase plate heat exchanger according to one of the preceding claims, characterized in that the primary medium (1) is the hot and humid fresh air (15) of the environment of a room to be cooled and the secondary medium (2) is the used dry and cool exhaust air (16) of this cooled room which flows in countercurrent to the primary medium (1), and that the inner surfaces of the plate gaps (1a) for the primary medium are wetted with hygroscopic solution (17a), wherein liquid (3) and primary medium (1) flow in opposite directions while the inner surfaces of the plate gaps (2a) for the secondary medium (2) are wetted with water (18) which can flow in any direction.

9. Multi-phase plate heat exchanger according to one of the preceding claims, characterized in that the primary medium (1) is the hot and moist fresh air (15) of the environment of a room to be cooled, and that the inner surfaces of the plate gaps (1a) for the primary medium (1) are wetted with diluted hygroscopic solution (17c) additionally preheated according to claim 4 in countercurrent to the primary medium (1), and that the secondary medium (2) which flows in countercurrent to the primary medium (1) is the same but heated fresh air (15c) which is heated after the primary passage through the multi-phase heat exchanger (14) and is almost saturated with additional steam (20), and that condensation water forms on the inner surfaces of the plate gaps (2a) for the secondary medium (2) during its cooling, which water leaves the multi-phase heat exchanger (14) cooled in direct current with the secondary medium (2).

10. Multi-phase plate heat exchanger according to one of the preceding claims, characterized in that the multi-phase plate heat exchanger is positioned such that its plates are horizontal and there are grooves or shafts transverse to the direction of flow.

11. Combination of 2 multi-phase plate heat exchangers according to one or more of claims 1 to 8, characterized in that the exhaust air (16)

of a room (B) to be cooled is isenthalpically humidified and cooled to its dew point in a first multi-phase plate heat exchanger (14) serving as an air humidifier (14c) and is then humidified and heated in a second multi-phase plate heat exchanger (14) on the one hand by water (18) and is fed in countercurrent to a hot moist fresh air (15) coming from the environment (A) on the other hand, which is simultaneously dried by a hygroscopic solution (17a,17b) and cooled down to close to the dew point of the room (B) to be cooled.

12. Combination of 2 multi-phase plate heat exchangers according to claim 11 with a third multi-phase plate heat exchanger according to one of claims of 1 to 8, characterized in that the dried fresh air (15) coming from the second multi-phase plate heat exchanger (14) and cooled down to close to the dew point of the room (B) to be cooled is even further cooled isenthalpically in the third multi-phase plate heat exchanger (14) serving as air humidifier (14c).
13. Combination of multi-phase plate heat exchangers according to one of claims 11 or 12 with a multi-phase plate heat exchanger (14) according to one of claims from 1 to 8 serving as an air dryer (14d), characterized in that the warm moist fresh air (15) from the environment (A) is first predried in a multi-phase plate heat exchanger (14) serving as an air dryer (14d) under isenthalpic heating by means of hygroscopic solution (17a, 17b) before it is cooled in the actual multi-phase plate heat exchanger (14) in countercurrent to the exhaust air (16) and is further dried with hygroscopic solution (17a, 17b).
14. Combination of 3 multi-phase plate heat exchangers according to one of claims of 1 to 8, characterized in that exhaust air (16) from a room (B) to be heated is humidified isenthalpically in a first multi-phase plate heat exchanger (14) serving as an air humidifier (14c) and is then dried on the one hand in a second multi-phase plate heat

exchanger (14) with hygroscopic solution (17a, 17b) and is fed on the other hand in countercurrent to cold fresh air (15) coming from the environment (A), which is simultaneously humidified by water (18) and heated by drying the exhaust air (16), and wherein this humidified and slightly heated fresh air is isenthalpically dried and heated in a third multi-phase plate heat exchanger (14) serving as an air dryer (14d) and from there is supplied for heating the room -B-.

15. Combination of 2 multi-phase plate heat exchangers according to one of claims of 1 to 8 which serves the regeneration of diluted hygroscopic solution (17b) in order to convert it again into concentrated hygroscopic solution (17a) by dehydration, characterized in that fresh air (15) is fed into the primary side (14a) of a first multi-phase plate heat exchanger (14), where it flows in countercurrent to heated diluted hygroscopic solution (17c) which wets the active surface (13a) of this multi-phase plate heat exchanger (14) and, after it has heated and is almost saturated with moisture, into a second, a multi-phase plate heat exchanger (14) serving as an air humidifier (14c), where the active surface (13a) is wetted with hot water so that the fresh air (15) is further heated and humidified, and where this fresh air (15) is then again directed to the first multi-phase plate heat exchanger (14) but to its secondary side (14b), where it cools down again and condenses the excess steam on the active surface (13a) of said first multi-phase plate heat exchanger (14), thereby providing the heat required for dehydration from the diluted hygroscopic solution (17b).