

### **Apparatus for drying and/or cooling gas**

5 The invention relates to an apparatus for drying and/or cooling gas, in particular air, by means of a hygroscopic solution. Such an apparatus can be used, for example, in air conditioning plants or the like.

Hygroscopic solutions have the property of binding moisture from the  
10 environment. A corresponding hygroscopic solution can comprise, for example, an aqueous saline solution of in particular lithium chloride, lithium bromide, calcium chloride, one of the newly developed, so-called ionic solutions and/or the like. The absorption capability of such a solution increases inter alia as the temperature drops.

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Document JP 11 051421 A describes an apparatus for drying gas by means of a hygroscopic solution. The apparatus includes a gas flow passage and a flow passage conducting the hygroscopic solution. A membrane is provided which is permeable for moisture and which allows  
20 moisture to be transferred from the gas via the membrane into the hygroscopic solution and to be absorbed therein.

It is the object of the invention to provide an improved apparatus of the initially named kind which ensures a drying performance or cooling  
25 performance which is as high as possible with a design which is as simple and compact as possible.

This object is satisfied in accordance with the invention by an apparatus for drying and/or cooling gas, in particular air, by means of a hygroscopic

solution, having an absorption device which comprises at least one gas flow passage as well as at least one flow passage conducting the hygroscopic solution, wherein the inner space or gas space of a respective gas flow passage is bounded at least partly by vapor-permeable, liquid  
5 tight membrane wall and at least one flow passage is provided which conducts the hygroscopic solution and is formed between such a gas flow passage and a further such gas flow passage adjacent thereto or an adjacent cooling unit so that moisture, in particular water vapor, in transferred from the gas via the membrane wall into the hygroscopic  
10 solution and is absorbed therein. The absorption device comprises a plurality of gas flow passages in parallel with one another as well as a plurality of flow passages in parallel with one another and conducting the hygroscopic solution. The flow passages of the absorption device conducting the hygroscopic solution are respectively formed between a gas  
15 flow passage and an adjacent cooling unit. A respective cooling unit in this respect preferably comprises a cooling fluid space at least partly bounded by a fluid-tight, heat-conducting wall.

The apparatus can be kept relatively simple and compact with a relatively  
20 large drying performance and cooling performance due to this design. In particular a larger number of gas flow passages can also be provided without problem, whereby the performance capability can be correspondingly further increased.

25 The hygroscopic solution flows through the absorption device, preferably in counterflow to the gas.

In accordance with a preferred practical embodiment of the apparatus in accordance with the invention, the hygroscopic solution exiting the absorption device is supplied to a regeneration device in which it is regenerated. The regenerated hygroscopic solution can then again be  
5 supplied to the absorption device.

The regenerated hygroscopic solution can be supplied to the absorption device via a cooler. The absorption capability of the hygroscopic solution reused in the absorption device is further increased by the additional  
10 cooling.

The gas exiting the absorption device is preferably supplied to a consumer.

In particular with a consumer with little gas loss, the gas coming from the  
15 consumer can be supplied to the regeneration device. It can be of advantage in this respect if the gas coming from the consumer is supplied to the regeneration device via a heat exchanger in which the gas is preferably heated.

20 Whereas the gas moisture increases again in the consumer, for example, the relative humidity is reduced again by such a heat exchanger.

In specific cases, however, it can also be of advantage if the gas coming from the consumer is led off as exhaust gas or exhaust air.

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In this case, gas not coming from the consumer, for example, in particular inflow air such as environmental air, can be supplied to the regeneration device. The regeneration device can, however, generally also be operated without any supplied gas.

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If the regeneration device is flowed through by a gas, it is advantageous if the hygroscopic solution flows through the regeneration device in counterflow to the gas.

- 5 In accordance with a preferred practical embodiment of the apparatus in accordance with the invention, the regeneration device comprises at least one gas flow passage as well as at least one flow passage conducting the hygroscopic solution, with the inner space or gas space of a respective gas flow passage being at least partly bounded by a vapor-permeable, liquid-tight membrane wall and at least one flow passage being provided which  
10 conducts the hygroscopic solution and is formed between such a gas flow passage and a further such gas flow passage adjacent thereto or an adjacent heating unit so that moisture, in particular water vapor, is transferred into the gas from the hygroscopic solution via the membrane  
15 wall and the hygroscopic solution is concentrated.

In this respect, the regeneration device advantageously comprises a plurality of gas flow passages in parallel with one another as well as a plurality of flow passages in parallel with one another and conducting the  
20 hygroscopic solution.

In this respect, it can be of advantage in specific cases if the flow passages of the regeneration device conducting the hygroscopic solution are respectively formed between two mutually adjacent flow passages.

25 Such embodiments are, however, also conceivable in which the flow passages of the regeneration device conducting the hygroscopic solution are respectively formed between a gas flow passage and an adjacent heating unit.

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A further preferred practical embodiment of the apparatus in accordance with the invention is characterized in that the regeneration device has at least one condensation/evaporation stage which is flowed through by the hygroscopic solution exiting the absorption device and which comprises at  
5 least one condensation unit and at least one evaporator unit, with a respective condensation unit comprising a first vapor space at least partly bounded by a condensation wall and a respective evaporator unit comprising a second vapor space at least partly bounded by a vapor-permeable, liquid-tight membrane wall and with at least one flow passage  
10 being provided which conducts the hygroscopic solution and is formed between such a condensation unit and such an evaporator unit adjacent thereto so that the hygroscopic solution is heated via the condensation wall and the vapor arising from the hygroscopic solution arrives through the membrane wall in the second vapor space.

15 In this respect, the regeneration device expediently has a heating stage which is flowed through by the hygroscopic solution exiting the condensation/evaporation stage and which comprises at least one heating unit and at least one evaporator unit, with a respective heating unit  
20 comprising a heating fluid space at least partly bounded by a fluid-tight, heat-conducting wall and a respective evaporator unit comprising a vapor space at least partly bounded by a vapor-permeable, liquid-tight membrane, with at least one flow passage being provided which conducts the hygroscopic solution and is formed between a heating unit and an  
25 evaporator unit adjacent thereto so that the hygroscopic solution is heated via the fluid-tight, heat-conducting wall and the vapor arising from the hygroscopic solution arrives through the membrane wall in the vapor space and the vapor arising in this vapor space is preferably supplied to a condensation unit of the condensation/evaporation stage.

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The regeneration device preferably comprises a condensation stage having at least one cooling unit and at least one condensation unit, with a respective cooling unit comprising a cooling fluid space at least partly bounded by a fluid-tight, heat-conducting wall and a respective

5 condensation unit comprising a vapor space at least partly bounded by a condensation wall and with at least one cooling unit being directly adjacent to at least one condensation unit in the condensation stage so that the condensation wall of the respective condensation unit is cooled via the cooling unit. In this respect, vapor arising in a preceding

10 condensation/evaporation stage is preferably supplied to the condensation stage.

If the regeneration devices comprises the previously mentioned system of at least one condensation/evaporation stage, heating stage and preferably

15 also condensation stage, this system is preferably in a vacuum, the cooling fluid and the heating fluid are preferably at environmental pressure and the hygroscopic solution is preferably in a vacuum. In the condensation stage(s)/evaporation stage(s) and in the heating stage, the hygroscopic solution can in particular be at the boiling temperature

20 corresponding to the absolute pressure in the vapor space of a respective adjacent evaporator unit over all stages, as is described in WO 2007/054311 which is herewith included in the disclosure content of the present application.

25 A respective heating unit of the heating stage can be flowed through by a heating fluid which is, for example, heated by solar power.

The vapor entering into a respective condensation unit of the condensation/evaporation stage condenses at the condensation surfaces.

30 The corresponding heat is transferred to the hygroscopic solution via the

respective surface. The vapor arising therein passes through the membrane of the adjacent evaporator unit into its vapor space which communicates with the pressure of the vapor space of the respective condensation unit of the following condensation/evaporation stage in the case of a plurality of condensation stages/evaporation stages.

In accordance with a preferred practical embodiment of the apparatus in accordance with the invention, it is designed as a modular flow system having a plurality of frame elements. In this respect, the different functional units such as in particular a respective gas flow passage, a respective cooling unit, a respective heating unit, a respective condensation unit and/or a respective evaporator unit are each provided in the form of such a frame element.

The frame elements are preferably provided with web structures via which they can in particular be connected to one another for forming the absorption device, the regeneration device, a respective condensation/evaporation stage, the heating stage and/or the condensation stage.

The frame elements can each comprise an inner region which is surrounded by an outer frame and which is preferably provided with an in particular grid-like spacer to whose two sides a respective corresponding functional surface, preferably in the form of a film or membrane, is in particular applied for forming a respective inner space or gas space, a respective vapor space, a respective heating fluid space or a respective cooling fluid space.

The web structures via which the individual frame elements can be connected to one another can, for example, be welded web structures or

bonded structures via which the frame elements are welded or bonded to one another. In the case of welded web structures, a friction welding process, a laser welding process and/or a heating element welding process can be used, for example, for connecting the frame elements.

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The gas drying apparatus and/or gas cooling apparatus can be designed in a particularly simple manner and can be varied in the desired manner using the frame elements in accordance with the invention. The frame elements or the units or stages obtained via them are characterized by a relatively simple form and provide different possibilities of the gas supply or air supply, cooling fluid supply and heating fluid supply. The respective drying processes and/or cooling processes as well as the regeneration processes can, for example, be realized only with membrane frame elements or with a combination of membrane frame elements and film frame elements, with frame elements also being conceivable which are provided with a membrane on the one side and with a film on the other side.

The invention will be explained in more detail in the following with reference to embodiments and to the drawing; there are shown in this:

Fig. 1      a schematic representation of an exemplary embodiment of an apparatus for drying and/or cooling gas in which the gas exiting the absorption device is supplied to a consumer and the gas coming therefrom is supplied to a regeneration device and both the absorption device and the regeneration device each include at least one flow passage conducting the hygroscopic solution and formed between two gas flow passages;

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- Fig. 2 a schematic representation of an exemplary embodiment of the apparatus comparable with the embodiment in accordance with Fig. 1, with the regeneration device, however, comprising at least one flow passage formed between a gas flow passage and a heating unit and conducting the hygroscopic solution;
- Fig. 3 a schematic representation of an exemplary embodiment of an apparatus for drying and/or cooling gas in which the gas coming from the consumer is led off as exhaust gas or exhaust air and gas not coming from the consumer is supplied to the regeneration device and the absorption device comprises at least one flow passage conducting the hygroscopic solution and formed between a gas flow passage and a cooling unit and the regeneration device again comprises at least one flow passage conducting the hygroscopic solution and formed between a gas flow passage and a heating unit;
- Fig. 4 a schematic representation of an exemplary embodiment of an apparatus for drying and/or cooling gas in which the gas coming from the consumer is led off as exhaust gas or exhaust air, the absorption device again comprises at least one flow passage formed between a gas flow passage and a cooling unit and conducting the hygroscopic solution and the regeneration device comprises at least one condensation/evaporation stage, a heating stage and preferably a condensation stage;

- Fig. 5 a schematic representation of an exemplary embodiment of a frame element which can in particular be used both as a cooling unit and as a heating unit as well as a condensation unit;
- 5 Fig. 6 a schematic representation of an exemplary embodiment of a frame element e.g. forming a gas passage or air passage or an evaporator unit; and
- 10 Fig. 7 a schematic representation of an exemplary embodiment of a frame element square in cross-section.

Mutually corresponding parts have the same reference numerals associated with them in the different Figures.

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Figs. 1 to 3 show in a schematic representation a respective exemplary embodiment of an apparatus 10 for drying and/or cooling gas 12 by means of a hygroscopic solution 14, with the gas 12 being able to be air, for example.

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In this respect, the apparatus 10 comprises an absorption device 16 having at least one gas flow passage 18 as well as at least one flow passage 20 conducting the hygroscopic solution 14. In this respect, the inner space or gas space 22 of a respective gas flow passage 18 is at least

25 partly bounded by a vapor-permeable, liquid-tight membrane wall 24.

At least one flow passage 20 is provided which conducts the hygroscopic solution (14) and is formed between such a gas flow passage 18 and a further such gas flow passage 18 adjacent thereto (cf. Figs. 1 and 2) or an

30 adjacent cooling unit 26 (cf. Figs. 3 and 4) so that moisture, in particular

water vapor, is transferred from the gas 12 via the membrane wall 24 into the hygroscopic solution 18 and is absorbed therein.

5 In this respect, the hygroscopic solution 14 can flow through the absorption device 16 in counterflow to the gas 12.

The absorption device 16 can comprise a plurality of gas flow passages 18 in parallel with one another as well as a plurality of flow passages 20 in parallel with one another and conducting the hygroscopic solution 14.

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As can be seen from Figs. 1 and 2, the flow passages 20 of the absorption device 16 conducting the hygroscopic solution 14 can respectively be formed between two mutually adjacent gas flow passages 18.

15 However, in particular such embodiments are also conceivable in which the flow passages 20 of the absorption device 16 conducting the hygroscopic solution are respectively formed between a gas flow passage 18 and an adjacent cooling unit 26 (cf. Figs. 3 and 4). In this respect, a respective cooling unit 26 preferably comprises a cooling fluid space 54 at  
20 least partly bounded by a fluid-tight, heat-conducting wall 48.

The hygroscopic solution 14 exiting the absorption device 16 can be supplied to a regeneration device 28 in which it is regenerated. The regenerated hygroscopic solution 14 is then preferably again supplied to  
25 the absorption device 16.

As can be seen from Figs. 1 and 2, the regenerated hygroscopic solution 14 can in particular be supplied to the absorption device 16 via a cooler 30.

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The gas 12 exiting the absorption device 16 can be supplied to a consumer 32.

It is of advantage in specific cases if the gas 12 coming from the consumer 32 is supplied to the regeneration device 28 (cf. Figs. 1 and 2).

In this respect, the gas 12 coming from the consumer 32 can be supplied to the regeneration device 28 via a heat exchanger 34 in which the gas 12 is preferably heated.

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The gas 12 coming from the consumer 32 can, however, also be led off as exhaust gas or exhaust air (cf. Figs. 3 and 4).

In this respect gas 12' not coming from the consumer 32, in particular inflow air such as environmental air, can be supplied to the regeneration device 28, for example (cf. Fig. 3). Such embodiments are, however, also conceivable in which the regeneration device 28 is not flowed through either by gas coming from the consumer 32 or by gas not coming from the consumer (cf. Fig. 4, for example).

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In the event that the regeneration device 28 is flowed through by gas, the hygroscopic solution 14 can in particular flow through the regeneration device 28 in counterflow to the gas 12, 12' (cf. Figs. 1 to 3).

As can in particular again be seen from Figs. 1 to 3, the regeneration device 28 can comprise at least one gas flow passage 18 as well as at least one flow passage 20 conducting the hygroscopic solution 14, with the inner space or gas space 22 of a respective gas flow passage 18 being at least partly bounded by a vapor-permeable, liquid-tight membrane wall 24 and with at least one flow passage being provided which conducts the

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hygroscopic solution 14 and is formed between such a gas flow passage 18 and such a further gas flow passage 18 adjacent thereto (cf. Fig. 1) or an adjacent heating unit 36 (cf. Figs. 2 and 3) so that moisture, in particular water vapor, is transferred into the gas 12 or 12' from the hygroscopic solution via the membrane wall 24 and the hygroscopic solution 14 is concentrated.

In this respect, the regeneration device 28 can comprise a plurality of gas flow passages 18 in parallel with one another as well as a plurality of flow passages 20 in parallel with one another and conducting the hygroscopic solution 14 (cf. Figs. 1 to 3).

In particular in the latter case, the flow passages 20 of the regeneration device 28 conducting the hygroscopic solution can respectively be formed between two mutually adjacent gas flow passages 18 (cf. Fig. 1). Such embodiments are, however, also conceivable in which the flow passages 20 of the regeneration device 28 conducting the hygroscopic solution 14 are respectively formed between a gas flow passage 18 and an adjacent heating unit 36.

The regeneration device 28 can, for example, also have at least one condensation/evaporation stage 38 which is flowed through by the hygroscopic solution 14 exiting the absorption device 16 and which comprises at least one condensation unit K and at least one evaporator unit V (cf. Fig. 4).

In this respect, a respective condensation unit K comprises a first vapor space 42 at least partly bounded by a condensation wall 40 and a respective evaporator unit V comprises a second vapor space 44 at least partly bounded by a vapor-permeable, liquid-tight membrane wall 24. In

this respect, at least one flow passage 20 which conducts the hygroscopic solution 14 and is formed between such a condensation unit K and such an evaporator unit V adjacent thereto is provided in a respective condensation/evaporation stage 38. The hygroscopic solution 14 is in this  
5 respect heated via the condensation wall 40 and the vapor arising from the hygroscopic solution 14 arrives through the membrane wall 24 in the second vapor space 44.

In addition, the regeneration device 28 can have a heating stage 46 which  
10 is flowed through by the hygroscopic solution 14 exiting the condensation/evaporation stage 38 and which comprises at least one heating unit 36 and at least one evaporator unit V (cf. Fig. 4 again).

In this respect, a respective heating unit 36 comprises a heating fluid  
15 space 50 at least partly bounded by a fluid-tight, heat-conducting wall 48 and a respective evaporator unit V comprises a vapor space 44 at least partly bounded by a vapor-permeable, liquid-tight membrane wall 24. At least one flow passage 20 which conducts the hygroscopic solution 14 and is formed between a heating unit 36 and an evaporator unit V adjacent  
20 thereto is provided in the heating stage 46 so that the hygroscopic solution 14 is heated via the fluid-tight, heat-conducting wall 48 and the vapor arising from the hygroscopic solution 14 arrives through the membrane wall 24 in the vapor space 44. The vapor arising in this vapor space 44 is preferably supplied to a condensation unit K of the  
25 condensation/evaporation stage 38 (cf. Fig. 4 again).

As can likewise again be seen from Fig. 4, the regeneration device 28 can also comprise a condensation stage 52 having at least one cooling unit 26 and at least one condensation unit K. In this respect, a respective cooling  
30 unit 26 has a cooling fluid space 54 at least partly bounded by a fluid-

tight, heat-conducting wall 48 and a respective condensation unit K has a vapor space 42 at least partly bounded by a condensation wall 40. At least one cooling unit 26 is directly adjacent to at least one condensation unit K in the condensation stage 52 so that the condensation wall 40 of the  
 5 respective condensation unit K is cooled via the cooling unit 26. Vapor arising in a preceding condensation/evaporation stage 38 is preferably supplied to this condensation unit K.

A respective apparatus 10 for drying and/or cooling gas can in particular  
 10 be designed as a modular flow system having a plurality of frame elements (cf. Figs. 5 to 7). In this respect, the different functional units such as in particular a respective gas flow passage 18, a respective cooling unit 26, a respective heating unit 36, a respective condensation unit K and/or a respective evaporator unit V are each provided in the form of such a frame  
 15 element. The frame elements are preferably provided with web structures 56 via which they can in particular be connected to one another for forming the absorption device 16, the regeneration device 28 or a respective condensation/evaporation stage 38, the heating stage 46 and/or the condensation stage 38 of the regeneration device 28. The frame  
 20 elements can each comprise an inner region 60 which is surrounded by an outer frame 58 and which is preferably provided with an in particular grid-like spacer 62 to whose two sides a respective corresponding functional surface, preferably in the form of a film or membrane, is in particular applied for forming a respective inner space or gas space 22, a  
 25 respective vapor space 42, 44, a respective heating fluid space 50 or a respective cooling fluid space 54 etc.

In this respect, a respective membrane can in particular take over the function of a membrane wall 24 and a respective film can in particular

take over the function of a condensation wall 40 or of a fluid-tight, heat-conducting wall 48.

The different frame elements can, for example, be welded or adhesively bonded to one another via the web structures. If, for example, welding web structures are used, a friction welding process, a laser welding process and/or a heating element welding process can be used for connecting the frame elements, for example.

Fig. 5 shows in a schematic representation an exemplary embodiment of a frame element which can be used, for example, both as a cooling unit and as heating unit 26 and 36 respectively. The spacer 62 can in particular be provided with a respective film on both sides in the present case. The heating fluid space or cooling fluid space 50 or 54 respectively formed between the films is flowed through by heating fluid or cooling fluid, e.g. water. The heating fluid or cooling fluid is supplied to and again removed from the heating fluid space or cooling fluid space 50 and 54 respectively via passages 64, for example water passages. The passages 64 are connected to leadthroughs 66 in particular provided in the corner regions of the frame element and in particular for the heating fluid or cooling fluid. Leadthroughs 68 are additionally in particular provided for the hygroscopic solution 14 in particular in the region of the leadthroughs 66.

The leadthroughs 66, 68 provided on the left hand side of Fig. 5 can be provided, for example, for a heating fluid inlet or cooling fluid inlet or for a solution inlet and the leadthroughs 66, 68 provided on the right hand side of Fig. 5 can be provided, for example, for a heating fluid outlet or cooling fluid outlet or for a solution outlet. The inlet and outlet for the fluid or the solution respectively can, however, also generally be otherwise arranged.

Parallel flows, counter flows or crossflows can be realized, for example, via these leadthroughs 66, 68.

5 The frame element is, for example, rectangular in cross-section in the present case. Generally, however, a square form is also conceivable, for example (cf. Fig. 7, for example).

The leadthroughs 66 can, for example, respectively be delineated toward the inner region 60 by a web section 70.

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The frame element in accordance with Fig. 5 having films in particular provided at both sides can in particular also be provided as a condensation unit K, with in this case a corresponding vapor space 44 being able to be formed between the films.

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Fig. 6 shows in a schematic representation an exemplary embodiment of a frame element e.g. forming a gas flow passage, an air flow passage or an evaporator unit V. In the present case, a respective vapor-permeable, water-tight membrane can in particular be applied to both sides of the  
20 spacer 62. The frame element can in particular be open toward the inner region 60 e.g. on the two narrow sides for forming a gas flow passage or an air flow passage.

Leadthroughs 66, 68 as well as web sections 70 can also be recognized in  
25 the representation in accordance with Fig. 6.

This frame element shown in Fig. 6 is also again rectangular in cross-section.

The films and membrane can, for example, be adhesively bonded or welded to the frame elements. A different kind of fastening of these films and membranes is generally also conceivable.

- 5 Fig. 7 shows in a schematic representation an exemplary embodiment of a frame element square in cross-section. In this respect, in particular leadthroughs 66, 68 can also again be recognized in this representation.

In the case of this frame element having a square cross-section, the  
10 leadthroughs 66, 68 are arranged rotationally symmetrically. On a rotation by 90°, leadthroughs of the same function therefore always come to line on one another in plan view. Classical crossflow apparatus can also be designed using such an arrangement. Such a circuit is achieved by rotating the frame elements by 90°.

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In another respect, this frame element can in particular again be designed such as was described with reference to Figs. 5 and 6.

The different frame elements can therefore be arranged relative to one  
20 another according to the function to be satisfied. In this respect, for example, a frame element provided in the form of a condensation unit K can in particular be spanned by condensation film and a frame element provided in the form of an evaporator unit V can in particular be spanned by membrane. A respective flow passage 20 conducting the hygroscopic  
25 solution 14 results between the membrane and the film by the bringing together of a frame element provided in the form of a condensation unit K and provided with a film and of a frame element provided in the form of an evaporator unit V and provided with a membrane. A spacer can still be inserted in this flow passage 20. Instead of such a spacer, the in  
30 particular grid-like spacer 46 can also be designed, for example, such that

defined passages for conducting the solution are formed on the filling of the flow passage 20.

As results from Fig. 1, a heat and mass transfer device can be realized using membrane frame elements, for example. Moist and hot air can, for example, be sent through the heat and mass transfer device which is an air cooler and air dryer in one.

So much concentrated hygroscopic solution can, for example, be conducted in counterflow through the flow passage bounded by membranes and conducting the hygroscopic solution that the air or gas flowing over the membranes is both dried and cooled. The solution is in this respect diluted and heated. The cooled and dried air is supplied to the consumer, for example to a ship or the like. In the consumer the air is heated again by loads such as electrical consumers and persons and the air humidity is increased by the consumer or by the persons. The return air, which in particular almost corresponds to the inflow air in large ships such as cruise ships, can be heated in a heat exchanger so that the relative humidity drops. In the desorber or regeneration device, this air comes into contact with the diluted solution via the membrane. Water is now expelled from the diluted solution. The solution is concentrated and is cooled by the evaporation of the water. In an optional downstream cooler, the concentrated solution can be cooled even further and can be supplied to the absorption device again.

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As can be seen from Fig. 2, for example, the heat and mass transfer device or the absorption device can, for example, be realized using membrane frame elements and the regeneration device can, for example, be realized using membrane frame elements and film frame elements. The regenerator or desorber is here therefore made up of membrane frame elements and

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film frame elements. Warm water flows, for example through the film frame elements in the desorber or regeneration apparatus and heats the solution and expels water from the solution. The evaporation heat is here provided, for example, by cooling the hot water from the heating circuit.

- 5 The air flowing in from the consumer is also heated via the heated solution and can take up moisture. The concentrated solution can be cooled via a cooler downstream of the desorber or regeneration device.

- As can be seen from Fig. 3, a cooled absorber or a cooled absorption  
10 device and a heated desorber or a heated regeneration device can be provided. Such a combination is in particular of advantage when outside air is respectively used for the absorber and the desorber in the respective plant. This is also a suitable process for a cold storage in a concentrated solution since a larger water charge of the solution can be achieved in the  
15 cooled absorber. The absorption and desorption can here also take place at separate locations. The concentrated solution could then be delivered to the consumer as a cold store. The diluted solution could then be returned.

- As can be seen from Fig. 4, a cooled absorber or a cooled absorption  
20 device can be provided in combination with a regeneration device which comprises a system serving for the concentration of the hygroscopic solution and having at least one condensation/evaporation stage as well as a heating stage and preferably a condensation stage. In this respect, the system within the broken line of Fig. 4 is in a vacuum. The cooling  
25 fluid and the heating fluid are at environmental pressure and the solution is in a vacuum. The circumstances are in this respect substantially as is described in WO 2007/054311. Such a combination is in particular efficient when no waste heat is available for the desorption of the solution. The energy requirement for the desorption can be considerably reduced  
30 over the number of different stages using a correspondingly multistage

concentration process. It is also of particular advantage that distilled water arises in the desorption process, that is water is acquired from the moist air.

- 5 As can be seen from Figs. 2 and 3, a heat exchanger 72 can, for example, be provided in the respective heating fluid circuit of the regeneration device 28.

- As can be seen from Fig. 4, cooling water 74 can, for example, be supplied  
10 to the condensation stage 52 or to its cooling units 26. The heating fluid for the heating units 36 of the heating stage 46 can be heated by solar power, for example.

- As can be seen from Figs. 3 and 4, for example, a cooler 76 can be  
15 associated with the cooling fluid circuit of the absorption device or of the cooled absorber.

- Instead of air, any desired other gas can generally also be provided. In addition, water vapor does not necessarily have to be removed in the  
20 respective dehumidification. Any desired other mass transfer can also take place on the dehumidification.

## Reference numeral list

|    |     |                                                  |
|----|-----|--------------------------------------------------|
|    | 10  | apparatus for drying and/or cooling gas          |
|    | 12  | gas                                              |
| 5  | 12' | gas not coming from the consumer                 |
|    | 14  | hygroscopic solution                             |
|    | 16  | absorption device, absorber                      |
|    | 18  | gas flow passage                                 |
|    | 20  | flow channel conducting the hygroscopic solution |
| 10 | 22  | inner space or gas space                         |
|    | 24  | membrane wall                                    |
|    | 26  | cooling unit                                     |
|    | 28  | regeneration device, desorber                    |
|    | 30  | cooler                                           |
| 15 | 32  | consumer                                         |
|    | 34  | heat exchanger                                   |
|    | 36  | heating unit                                     |
|    | 38  | condensation/evaporation stage                   |
|    | 40  | condensation wall                                |
| 20 | 42  | first vapor space                                |
|    | 44  | second vapor space                               |
|    | 46  | heating stage                                    |
|    | 48  | fluid-tight, heat-conducting wall                |
|    | 50  | heating fluid space                              |
| 25 | 52  | condensation stage                               |
|    | 54  | cooling fluid space                              |
|    | 56  | web structure                                    |
|    | 58  | outer frame                                      |
|    | 60  | inner region                                     |
| 30 | 62  | spacer                                           |

|    |    |                                                    |
|----|----|----------------------------------------------------|
|    | 64 | passage                                            |
|    | 66 | leadthrough for the heating fluid or cooling fluid |
|    | 68 | leadthrough for the hygroscopic solution           |
|    | 70 | web section                                        |
| 5  | 72 | heat exchanger                                     |
|    | 74 | cooling water                                      |
|    | 76 | cooler                                             |
|    | K  | condensation unit                                  |
| 10 | V  | evaporator unit                                    |

**Claims**

- 5     1.     An apparatus (10) for drying and/or cooling gas (12), in particular  
air, by means of a hygroscopic solution (14), having an absorption  
device (16) which comprises at least one gas flow passage (18) as  
well as at least one flow passage (20) conducting the hygroscopic  
10     solution (14), wherein the inner space or gas space (22) of a  
respective gas flow passage (18) is at least partly bounded by a  
vapor-permeable, liquid tight membrane wall (24) and at least one  
flow passage (20) is provided which conducts the hygroscopic  
solution (14) and is formed between such a gas flow passage (18)  
and a further such gas flow passage (18) adjacent thereto or an  
15     adjacent cooling unit (26) so that moisture, in particular water  
vapor, is transferred from the gas (12) via the membrane wall (24)  
into the hygroscopic solution (18) and is absorbed therein,  
characterized in that  
the absorption device (16) comprises a plurality of gas flow passages  
20     (18) in parallel with one another as well as a plurality of flow  
passages (20) in parallel with one another and conducting the  
hygroscopic solution; and  
in that the flow passages (20) of the absorption device (16)  
conducting the hygroscopic solution (14) are respectively formed  
25     between a gas flow passage (18) and an adjacent cooling unit (26),  
with a respective cooling unit (26) preferably comprising a cooling  
fluid space (54) at least partly bounded by a fluid-tight, heat-  
conducting wall (48).
- 30     2.     An apparatus in accordance with claim 1,

characterized in that  
the hygroscopic solution (14) flows through the absorption device  
(16) in counterflow to the gas (12).

- 5     3.     An apparatus in accordance with any one of the preceding claims,  
characterized in that  
the hygroscopic solution (14) exiting the absorption device (16) is  
supplied to a regeneration device (28) in which it is regenerated and  
the regenerated hygroscopic solution (14) is preferably again  
10     supplied to the absorption device (16).
4.     An apparatus in accordance with claim 3,  
characterized in that  
the regenerated hygroscopic solution (14) is supplied to the  
15     absorption device (16) via a cooler (30).
5.     An apparatus in accordance with any one of the preceding claims,  
characterized in that  
the gas (12) exiting the absorption device (16) is supplied to a  
20     consumer (32).
6.     An apparatus in accordance with claim 3,  
characterized in that  
the gas (12) coming from the consumer (32) is supplied to the  
25     regeneration device (28).
7.     An apparatus in accordance with claim 6,  
characterized in that

the gas (12) coming from the consumer (32) is supplied to the regeneration device (28) via a heat exchanger (34) in which the gas (12) is preferably heated.

- 5     8.     An apparatus in accordance with claim 5,  
characterized in that  
the gas (12) coming from the consumer (32) is led off as exhaust gas  
or as exhaust air.
- 10    9.     An apparatus in accordance with claim 8,  
characterized in that  
gas (12') not coming from the consumer (32), in particular inflow air  
such as environmental air, is supplied to the regeneration device  
(28).
- 15    10.    An apparatus in accordance with any one of the preceding claims,  
characterized in that  
the hygroscopic solution (14) flows through the regeneration device  
(28) in counterflow to the gas (12, 12').
- 20    11.    An apparatus in accordance with any one of the preceding claims,  
characterized in that  
the regeneration device (28) comprises at least one gas flow passage  
(18) as well as at least one flow passage (20) conducting the  
25    hygroscopic solution (14), with the inner space or gas space (22) of a  
respective gas flow passage (18) being at least partly bounded by a  
vapor-permeable, liquid-tight membrane wall (24) and with at least  
one flow passage (20) being provided which conducts the  
hygroscopic solution (14) and is formed between such a gas flow  
30    passage (18) and such a further gas flow passage (18) adjacent

thereto or an adjacent heating unit (36) so that moisture, in particular water vapor, is transferred into the gas (12, 12') from the hygroscopic solution via the membrane wall (24) and the hygroscopic solution (14) is concentrated.

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12. An apparatus in accordance with claim 11,  
characterized in that  
the regeneration device (28) comprises a plurality of gas flow  
passages (18) in parallel with one another as well as a plurality of  
10 flow passages (20) in parallel with one another and conducting the  
hygroscopic solution (14).
13. An apparatus in accordance with claim 12,  
characterized in that  
15 the flow passages (20) of the regeneration device (28) conducting the  
hygroscopic solution (14) are respectively formed between two  
mutually adjacent gas flow passages (18).
14. An apparatus in accordance with claim 12,  
20 characterized in that  
the flow passages (20) of the regeneration device (28) conducting the  
hygroscopic solution (14) are respectively formed between a gas flow  
passage (18) and an adjacent heating unit (36).
- 25 15. An apparatus in accordance with any one of the preceding claims, in  
particular in accordance with claim 8,  
characterized in that  
the regeneration device (28) has at least one  
condensation/evaporation stage (38) which is flowed through by the  
30 hygroscopic solution (14) exiting the absorption device (16) and

- which comprises at least one condensation unit (K) and at least one evaporator unit (V), with a respective condensation unit (K) comprising a first vapor space (42) at least partly bounded by a condensation wall (40) and a respective evaporator unit (V) comprising a second vapor space (44) at least partly bounded by a vapor-permeable, liquid-tight membrane wall (24) and with at least one flow passage (20) being provided which conducts the hygroscopic solution (14) and is formed between such a condensation unit (K) and such an evaporator unit (V) adjacent thereto so that the hygroscopic solution (14) is heated via the condensation wall (40) and the vapor arising from the hygroscopic solution (14) arrives through the membrane wall (24) in the second vapor space (44).
16. An apparatus in accordance with claim 15, characterized in that the regeneration device (28) has a heating stage (46) which is flowed through by the hygroscopic solution (14) exiting the condensation/evaporation stage (38) and which comprises at least one heating unit (36) and at least one evaporator unit (V), with a respective heating unit (36) comprising a heating fluid space (50) at least partly bounded by a fluid-tight, heat-conducting wall (48) and a respective evaporator unit (V) comprising a vapor space (44) at least partly bounded by a vapor-permeable, liquid-tight membrane wall (24), with at least one flow passage (20) being provided which conducts the hygroscopic solution (14) and is formed between a heating unit (36) and an evaporator unit (V) adjacent thereto so that the hygroscopic solution (14) is heated via the fluid-tight, heat-conducting wall (48) and the vapor arising from the hygroscopic solution (14) arrives through the membrane wall (24) in the vapor

space (44) and the vapor arising in this vapor space is preferably supplied to a condensation unit (K) of the condensation/evaporation stage (38).

- 5    17. An apparatus in accordance with claim 15 or claim 16, characterized in that  
the regeneration device (28) comprises a condensation stage (52) having at least one cooling unit (26) and at least one condensation unit (K), with a respective cooling unit (26) comprising a cooling  
10    fluid space (54) at least partly bounded by a fluid-tight, heat-conducting wall (48) and a respective condensation unit (K) comprising a vapor space (42) at least partly bounded by a condensation wall (40) and with at least one cooling unit (26) being directly adjacent to at least one condensation unit (K) in the  
15    condensation stage (K) so that the condensation wall (40) of the respective condensation unit (K) is cooled via the cooling unit (26), and with vapor preferably arising in a preceding condensation/evaporation stage (38) being supplied to the condensation stage (K).  
20
18. An apparatus in accordance with any one of the preceding claims, characterized in that  
it is designed as a modular flow system having a plurality of frame elements and the different functional units such as in particular a  
25    respective gas flow passage (18), a respective cooling unit (26), a respective heating unit (36), a respective condensation unit (K) and/or a respective evaporator unit (V) are respectively provided in the form of such a frame element, with the frame elements preferably being provided with web structures (56) via which they  
30    can in particular be connected to one another for forming the

absorption device (16), the regeneration device (28), a respective  
condensation/evaporation stage (38), the heating stage and/or the  
condensation stage (52) and respectively comprising an inner region  
(60) which is surrounded by an outer frame (58) and which is  
5 preferably provided with an in particular grid-like spacer (62) to  
whose two sides a respective corresponding functional surface,  
preferably in the form of a film or membrane, is in particular applied  
for forming a respective inner space or gas space (22), a respective  
vapor space (42, 44), a respective heating fluid space (50) or a  
10 respective cooling fluid space (54).