

DEVICE FOR CONTINUOUS AND EFFICIENT WATER ABSORPTION AND
REGENERATION OF DESICCANT, AN AIR COOLER, AND A METHOD FOR
CONTROLLING SUCH A DEVICE.

5 FIELD OF THE INVENTION

The present invention relates to a device for absorbing water from a gas and a
method of absorbing water from gas where the process is a continuous process
where a liquid desiccant is regenerated using a system that recovers the heat of
vaporization. The device may be used in a humidifier to prepare cool and humidified
10 air.

BACKGROUND

There are many ways of extracting water from air but many of them are struggling
with efficiency.

By using a liquid desiccant the vapor or water in the air may be absorbed and
15 stored in the desiccant. The amount of water that may be stored in a liquid
desiccant depends on the desiccant's ability to absorb water vapor at different
humidity. In order to use the same desiccant to absorb new vapor the desiccant
needs to be regenerated. When the liquid desiccant is heated the vapor pressure in
the desiccant increases. When the vapor pressure in the liquid desiccant becomes
20 higher than the surrounding vapor pressure the absorbed water is vaporised. In
this way liquid desiccant may be regenerated and reused. The amount of water, m ,
that may be absorbed/desorbed per second can be described by:

$$\frac{dm}{dt} = kA(P_m - P_a) \quad (1)$$

where $\frac{dm}{dt}$ is the amount of water absorbed/desorbed per second, k is a material
25 constant, A is the area of the liquid desiccant and the air, and P_m is the vapor
pressure in the liquid desiccant and P_a is the vapor pressure in the gas surrounding
the liquid desiccant.

Several methods for dehumidify air using a vapor compression system have been

invented. WO2011/062554 discloses a device for absorbing water or moisture from air using water absorbing material. The water is removed from said material by heating the material evaporating the water and letting the formed steam condensate on the walls of the device.

- 5 US5,351,497 discloses the use of a liquid desiccant in an air conditioner where the gas is treated with a liquid desiccant and being cooled at the same time. The liquid desiccant may be regenerated by heating the liquid desiccant in order to remove water.

10 The present inventors disclose in WO2018/009125 a device that absorbs moisture from air using a liquid desiccant which may be regenerated. The regeneration is achieved by heating the desiccant to evaporate the water which is then compressed and condensed in a heat exchanger. To lower the temperature of the regenerated liquid desiccant and for the device to be more energy efficient the regenerated liquid desiccant is heat exchanged with used liquid desiccant about to be regenerated.

15 US22060130654 teaches a method and a device for separating water from air using a hygroscopic liquid and teaches also how to remove absorbed water from the obtained water rich liquid by heating. Both devices teaches a system where the heated concentrated liquid desiccant is heat exchanged with liquid desiccant about to be regenerated.

20 A problem when heat exchanging a liquid desiccant is that the risk of precipitation within the heat exchanger may lead to failure of the device. A way of avoiding such precipitation is to lower the concentration of the salt in the desiccant but then the amount of moisture uptake is significantly reduced as well as the efficiency of the device.

25 Sorption cooling technique today suffers from the large need of water in order to cool air. This is very limiting especially in regions where water is a scarcity.

WO2018/191807 discloses a system for conditioning air for enclosed spaces using a flowing desiccant and an air membrane exchanger membrane (LAMEE). The system encompasses a regenerator for regeneration of the desiccant which may be
30 mixed with the diluted desiccator.

Prior art systems are not energy and cost efficient enough for absorbing and producing water from air, especially not in less humid conditions. Additionally, there is a need for a system designed to be adapted to the surrounding conditions such ambient temperature and ambient relative humidity (RH).

5 SUMMARY OF THE INVENTION

The object of the present invention is to provide a device which overcomes the drawbacks of prior art. The present invention solves the problem of allowing an efficient water absorption and regeneration of liquid desiccant without jeopardizing the function of the device by more or less eliminating the risk for precipitation of salts. By allowing higher concentrations, near the saturation point, of the salt in the liquid desiccant the present invention becomes much more efficient than prior art especially in environments having a relative humidity (RH) of 50 or lower. Furthermore the present invention is configured to be as energy efficient as possible by optimizing the energy demanding step of regenerating the liquid desiccant.

15 In a first aspect the present invention relates to a device for absorbing water from a gas as defined in claim 1.

In a second aspect the present invention relates to an air cooler comprising the device according to the present invention further comprising a humidifier comprising a second housing operatively connected to the water absorption section for receiving air having means for dispensing water and optionally means for increasing the contact time and contact area between the gas and the water.

In a third aspect the present invention relates to a method of absorbing water or producing water from a gas such as air wherein the method comprises:

- detecting a concentration of liquid desiccant,
- 25 - transporting liquid desiccant to a liquid desiccant regenerating section when the detected concentration is at a predetermined value or below a predetermined value, said liquid desiccant having a first temperature,
- performing a regeneration for removing water from the liquid desiccant, the regeneration taking place in the liquid desiccant regenerating section at a second temperature and at a first pressure, wherein a first energy amount is used to set and maintain the first pressure during regeneration,
- 30

- transporting regenerated liquid desiccant from the liquid desiccant regenerating section for use in absorbing water, the regenerated liquid desiccant having a third temperature, wherein the first pressure is selected so that the first energy amount is at or below a maximum energy or predetermined maximum energy and so that a concentration of the regenerated liquid desiccant is a desired concentration and/or a difference between the third temperature and the first temperature is minimized.

In a fourth aspect the present invention relates to device for absorbing water comprising:

at least one water absorption section for absorbing water from a gas flow using a liquid desiccant, wherein the water absorption section is operatively connected to at least one liquid desiccant container for delivery of liquid desiccant to and from the water absorption section, wherein the at least one liquid desiccant container is further operatively connected to a liquid desiccant regenerating section for delivery of liquid desiccant to and from the at least one liquid desiccant container,

wherein the liquid desiccant regenerating section comprises

- at least one boiler comprising a container,
- a vacuum system operatively connected to the boiler for reducing the pressure in the container, and

wherein the device further comprises a control unit configured to obtain a concentration value of liquid desiccant and to be operatively connected to the vacuum system for controlling the vacuum system to reduce the pressure in the container to a first pressure during regeneration of liquid desiccant.

Thereby, absorption of water can be performed in an energy efficient way and by selecting the concentration or water activity of liquid desiccant, operation of the device for absorbing water can be controlled depending on what is suitable for each application of the present invention. The inventive method thus allows for a more cost and energy efficient operation of the device compared with prior art devices.

The energy consumption of the device can be kept below a maximum value by selecting the first pressure in such a way that the regeneration can be performed without using more than the maximum energy. In most applications this will involve selecting the first pressure to be as low as possible without requiring more
5 than the maximum energy, since this will also minimize the temperature difference.

Suitably, the regeneration is performed by bringing the liquid desiccant to a boiling temperature for releasing water from the liquid desiccant in the form of steam, and the second temperature is the boiling temperature. Thereby, water can be released in a reliable way and since the boiling temperature can be altered by adjusting the
10 pressure, increased control over both the release of water and of the energy requirements for the regeneration is achieved.

Also, the boiling temperature is preferably controlled by adjusting the first pressure in the liquid desiccant regenerating section. Thereby, the liquid desiccant can be brought to boil at a temperature given by the first pressure, where preferably the
15 second temperature is kept low to minimize the temperature difference between the liquid desiccant after regeneration and the liquid desiccant before regeneration. At the same time, the first pressure is advantageously selected so that the energy consumption is kept sufficiently low to optimize the total energy consumption and increase cost efficiency of the device.

20 Suitably, the third temperature is equal to the second temperature. This is achieved by avoiding additional temperature increases after release of water from the liquid desiccant, and has the advantage that the temperature difference between the liquid desiccant after regeneration and the liquid desiccant before regeneration is further minimized.

25 Suitably, the predetermined value for the concentration of liquid desiccant is at least 33%, or at least 34%, or at least 35%. Thereby, the concentration can be selected as a concentration of salt in the liquid desiccant where regeneration should be performed in order to maintain an efficiency of the absorption of water. The concentration is suitably chosen depending on factors such as flow in the device
30 and an ambient humidity and/or ambient temperature.

Preferably, the method further comprises cooling the regenerated liquid desiccant to the first temperature. Thereby, by adding a separate cooling step after regeneration has taken place, the temperature difference can be made very small or even zero in order to further increase efficiency of the device when operating to absorb water.

- 5 Suitably, the method also comprises detecting an ambient temperature and cooling the regenerated liquid desiccant to the ambient temperature or lower. Thereby, operation of the device can be further improved and a heating of the liquid desiccant that generally takes place during the absorption of water can be counteracted so that the absorption is further improved.
- 10 Preferably, the liquid desiccant that is transported to the liquid desiccant regenerating section for regeneration is less than 0.25 of a total amount of liquid desiccant in the device for absorbing water, preferably less than 0.1 of the total amount and more preferably less than 0.05 of the total amount. Thereby, regeneration of a smaller amount can take place during normal operation of the
- 15 device, avoiding operation interruptions for the purpose of regeneration while simultaneously improving the absorption by regenerating the liquid desiccant.

- Suitably, the regenerated liquid desiccant is mixed with further liquid desiccant that is not regenerated and used for absorbing water from a gas in the absorption section of the device. Thereby, the concentration of liquid desiccant is changed
- 20 more slowly allowing the operation of the device to be performed at desired operating conditions that are not significantly altered by a simultaneous regeneration taking place. Also, the flow of liquid desiccant to be regenerated can be kept small so that the energy required for the regeneration is also small.

- Preferably, the concentration or conductivity is determined at predetermined
- 25 intervals and further liquid desiccant is transported to the regeneration section for regeneration as long as the concentration is below the predetermined value. Thereby, the regeneration can be commenced as soon as the concentration of liquid desiccant is at the predetermined value, and the regeneration can be continued until sufficient amounts of liquid desiccant have been regenerated so that a
- 30 concentration in a total available amount of liquid desiccant is once again above the predetermined value.

Suitably, the transporting of liquid desiccant to and from the regeneration section is performed at at least one condition for minimizing precipitation of the salt, said condition preferably being a pressure above a second pressure or a temperature above a fourth temperature. Thereby, precipitation of the salt can be avoided and
5 conduits of the device kept clean so that operation is not hindered or decreased due to precipitation that is transported in the liquid desiccant or becomes attached to internal walls and the like.

Suitably, the desired or predetermined desired concentration of the regenerated liquid desiccant is an optimal concentration at which a concentration of the
10 regenerated liquid desiccant mixed with liquid desiccant in a liquid desiccant collecting container or mixed with liquid desiccant to be dispensed is at or above the predetermined value. Thereby, regeneration of a smaller amount of liquid desiccant will serve to bring the concentration of a larger amount of liquid desiccant in the collecting container to the predetermined value so that no further
15 regeneration is necessary.

The desired concentration may be preset but could advantageously instead be determined based on at least one parameter such as an ambient temperature and an ambient humidity. Thereby, the device can operate in an efficient way since the concentration of liquid desiccant during absorption of water can be maintained at a
20 level suited to the particular application in a given location.

According to a fourth aspect of the invention, a data processing device comprising means for carrying out the method is provided, said data processing device preferably being a control unit of the device for absorbing water. Also provided is a computer program product comprising instructions which, when the program is
25 executed by a computer, cause the computer to carry out the method, as well as a computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the method.

Many additional advantages and benefits of the present invention will become readily apparent to the skilled person in view of the detailed description below. The
30 embodiments presented below are applicable to all aspects of the present invention.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1a)-c) schematic views of cross-sections of the present invention. A) discloses an illustration of the three sections water absorption section (α), liquid desiccant container (β) and regenerating liquid desiccant section (γ), b) shows a cross sectional view of an embodiment of the regenerating section (γ) and c) shows a cross sectional view of another embodiment of the regenerating section (γ) .

Figure 2a)-b), schematic views of cross-sections of embodiments of regenerating liquid desiccant section according to the present invention.

Figure 3a)-b), a schematic view of a cross-section of an embodiment of the present invention where the liquid desiccant in the storage tank is heat exchanged with the cooling media in the heat pump.

Figure 4a)-b), schematic views of a cross-sections of an embodiment of the present invention with two water absorption sections (α) per each regenerating section (γ).

Figure 5, a) schematic views of cross-sections of an embodiment of the present invention with the three sections for water absorption (α), liquid desiccant container (β), regenerating liquid desiccant (γ) and sorption cooling (λ), b) a schematic cross-sectional view from above of an embodiment of the water absorption section (α) with cooling pads or evaporation pads, c) a schematic cross-sectional view from above of an embodiment of the water absorption section (α) and d) a schematic cross-sectional view from above of an embodiment of the water absorption section (α) with a single pad.

Figure 6, schematic views of cross-sections of an embodiment of the present invention with the three sections for water absorption (α), liquid desiccant container (β), regenerating liquid desiccant (γ) and sorption cooling/humidifier (λ).

Figure 7, a schematic scheme of an embodiment of the method of adsorbing water from gas and regenerating a liquid desiccant.

Figure 8, a schematic scheme of an embodiment of the method of humidifying and cooling air.

Figure 9, a) a schematic scheme of the salt concentration and temperature of the liquid desiccant of prior art WO2018/009125, b) a schematic scheme of the salt concentration and temperature of the liquid desiccant according to an embodiment

of the present invention wherein the liquid regeneration section γ is a heat pump system, and c) a schematic scheme of the salt concentration and temperature of the liquid desiccant according to an embodiment of the present invention wherein the liquid regeneration section γ is a vapor compression system.

- 5 Figure 10, graphs disclosing a) capacity as a function of concentration and b) COP as function of concentration when regenerating a liquid desiccant with MgCl_2 in a boiler in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

10 In the present application the wordings “water absorbing material”, “water absorption material” and “hygroscopic material” are used interchangeably.

In the present application the wording “optimum temperature range” is a temperature range in which the third temperature **T3** (the temperature of the liquid desiccant leaving the liquid desiccant regenerating section γ) is as low as possible and that the difference between the third temperature **T3** and the first temperature
15 **T1** (the temperature of the liquid desiccant entering the liquid desiccant regenerating section γ) is as small as possible while still using less than a maximum energy for regeneration in the device **1**. Preferably the optimum temperature range is high enough so that precipitation of the absorbing material in the regenerated liquid desiccant is minimized or avoided when transported to the
20 liquid desiccant container β .

In the present application the wording “optimal concentration” is a concentration of the absorbing material in the regenerated liquid desiccant **S4** so that when the regenerated liquid desiccant is mixed with the liquid desiccant to be dispensed **S1** or mixed with the liquid desiccant in the liquid desiccant collecting container β
25 (such as the liquid desiccant collecting part **46** or liquid desiccant storage tank **48**) the concentration of the regenerated liquid desiccant mixed with the liquid desiccant **S2** in the liquid desiccant collecting container at least reaches a predetermined concentration at which regeneration is to be performed. Thus, the optimal concentration is the concentration that makes it unnecessary to perform
30 further regeneration since the concentration of liquid desiccant in the liquid desiccant collecting container is above the predetermined value. This optimal

concentration is dependent on the absorption material used and the selected quantity of liquid desiccant transported to the liquid desiccant regenerating section **Y**.

In the present application weight% and wt% are used interchangeably.

- 5 In the present application the wording “operatively connected” means that a part or section is connected to another part or section via suitable tubings or pipes allowing a flow of liquid or gas from one section or part to the subsequent section or part, or that they are connected in such a way that electric or electronic signals can pass from one part to another.
- 10 In the present application the wording “maximum energy” means an energy level at which regeneration of liquid desiccant in an energy efficient and thereby cost efficient way is possible. The maximum energy may be preset or predetermined or the maximum energy may be set based on the energy needed to obtain a first pressure **P1** in the container **3** and any energy needed to heat liquid desiccant in
- 15 said container **3** in order to regenerate liquid desiccant.

The enclosed figures and disclosed embodiments are only examples and are not limiting. Dotted lines in the figures are denoting communication between various parts or sections.

- The denotation of the liquid desiccant **S1**, **S1'-S4**, gas flow **A1-A4** and the water or
- 20 vapor **W1-W4** in the description herein should only be seen as schematic or illustrative and not limiting.

- In general **S1** denotes the liquid desiccant that is dispensed or to be dispensed, **S2** dispensed, collected liquid desiccant or collected dispensed liquid desiccant that has absorbed water and may have been mixed with **S4**, **S1'** liquid desiccant that is
- 25 returned to the means for dispensing liquid desiccant and may be mixed with **S4** prior to dispensing, **S3** the liquid desiccant entering the liquid desiccant regenerating section **Y** or the liquid desiccant to be regenerated and **S4** the regenerated or concentrated liquid desiccant exiting the liquid desiccant regenerating section **Y**. In general **A1** denotes the gas entering the adsorption
- 30 section, **A2** the gas exiting same section, **A3** denotes the gas **A2** that has been heated or heat exchanged and **A4** denotes the dehumidified gas exiting the

humidifier. In general **W1** denotes vapor generated during regeneration of liquid desiccant, **W2** the water dispensed in the humidifier, **W3** is the water exiting the humidifier and **W4** is the condensed water exiting the regenerating section.

Any measurement or detection of concentration of a water absorbing material or
5 absorbing material of any liquid is preferably done by measuring or detecting the conductivity of said liquid.

Any measurement or detection of boiling point of any liquid is preferably done by measuring or detecting the specific gravity of said liquid which results in the density and from there the boiling point of the liquid can be calculated.

10 The present invention relates to water absorption in air using a liquid desiccant. The device according to the present invention may be used for example, but not limited to, for dehumidification of indoor environments or in air-conditioning devices. A lower vapor pressure in the desiccant, i.e. the higher concentration of salt, results in a higher rate of absorption of water vapor. Therefore, it is desirable
15 to have a high concentration of absorbing material or salt in the liquid desiccant to absorb the water vapor in the air. However, there is a limit to how much salt can be dissolved in the liquid desiccant. This limit is temperature dependent where hot water can dissolve more salt.

To avoid formation of salt crystals in an evaporation or cooling process, the
20 concentration can never go above the maximum concentration limit. In an evaporation process, the liquid desiccant is heated to the boiling point where water is evaporated. Prior art have also suggested the use of heat exchangers in order to recover heat and thereby save energy. However, if the salt concentration in the desiccant reaches the maximum allowed concentration during the heat exchange
25 salt crystals will form in the heat exchanger and cause a break down and failure.

The present invention facilitates a higher salt concentration in the liquid desiccant and where the liquid desiccant dispensed has a low temperature leaving a more efficient water absorption process and device. The present invention further provides a device, method and system which allows absorbing water in a highly
30 energy efficient way through an innovative regenerating process.

Device for water absorption

The device according to the present invention is designed for water absorption from a gas, for example from air. The device may be integrated into another device or may be a standalone device and the device is suitable for producing water.

Referring now to figure 1a), b) and c). The device **1** according to the present invention comprises at least one water absorption section **a** which is adapted for
5 absorbing water from a gas **A1** using a liquid desiccant **S1**. The water or moisture uptake process results in gas **A2** with reduced moisture and a dispensed liquid desiccant **S2** with increased water content. The water absorption section **a** is operatively connected to at least one liquid desiccant container **β** for delivery of
10 liquid desiccant to (**S1/S1'**) and from (**S2**) the water absorption section **a**. The at least one liquid desiccant container **β** is further operatively connected to a liquid desiccant regenerating section **γ** for delivery of liquid desiccant to (**S4**) and from (**S3**) the at least one liquid desiccant container **β**. The liquid desiccant regenerating section **γ** is also operatively connected with a regenerated liquid desiccant container
15 **21** or the liquid desiccant container **β**, preferably via a regenerated liquid desiccant container **21**, for delivery of liquid desiccant **S4**.

The liquid desiccant regenerating section **γ** comprises at least one boiler **2** comprising a container **3** and a vacuum system **18** operatively connected to the container **3** and wherein said section preferably also comprises a regenerated liquid
20 desiccant container **21**.

The device preferably further comprises a control unit **19** configured to obtain, determine, detect or measure a concentration value of the water absorbing material in a liquid desiccant and to be operatively connected to the vacuum system **18** for
25 controlling the vacuum system **18** to reduce the pressure in the container **3** to a first pressure during regeneration of liquid desiccant. In a preferred embodiment the control unit **19** is configured to obtain or measure or detect or determine the concentration of the collected liquid desiccant **S2** (preferably by measuring the conductivity and temperature) in liquid desiccant container **β**, preferably also the temperature of the liquid desiccant to be regenerated **S3** and preferably also the
30 temperature and humidity (RH) of the surrounding atmosphere (the ambient temperature and relative humidity). Based on the ambient temperature and relative humidity and/or the concentration of the collected dispensed liquid desiccant **S2** in liquid desiccant container **β** the control unit **19** may be configured to set the

predetermined value or threshold value, i.e. the concentration at which regeneration of the liquid desiccant should be performed or when, and what quantity of, liquid desiccant in **β** should be transported to the regeneration section **γ**. In one embodiment the control unit **19** is configured to obtain or measure or
5 determine the concentration of the liquid desiccant to be dispensed **S1** and the concentration of the collected liquid desiccant **S2** and is further configured to set the predetermined value or threshold value based on ΔC , i.e. the difference between the concentration of the liquid desiccant to be dispensed **S1** and the collected dispensed liquid desiccant **S2** in the liquid desiccant container **β**. Preferably the
10 measurements, calculations or determinations conducted by the control unit **19** is based on what absorption material or salt is used in the liquid desiccant.

The device preferably also contains a heating unit **5**. One advantage with a heating unit **5** is that the liquid desiccant can be heated which means that the pressure in the container does not have to be reduced as much which saves energy. The
15 vacuum system **18** is configured to reduce the pressure in the container **3** and the heater **5** is operatively connected to the container **3** or arranged in the container **3** configured to heat the liquid desiccant in the container **3**. The preferred regenerated liquid desiccant container **21** is operatively connected to the container **3** for delivery of regenerated liquid desiccant **S4** from the container **3** and operatively connected
20 to the liquid desiccant container **β**, preferably the liquid desiccant collecting part **46**, or the means for dispensing the liquid desiccant **66**. In one embodiment the boiler **2** comprises a boiler housing comprising the container **3**, the heating unit **5** and the vacuum system **18** and preferably the regenerated liquid desiccant container **21**. In one embodiment the heating unit **5** is a heat pump or heat pump
25 system **8**. In another embodiment the vacuum system and heating unit **5** is a vapor compression system.

The vacuum system **18** and preferably also the heating unit **5** are configured to generate a regenerated liquid desiccant (**S4**) and is configured to do so in an energy efficient way in regards of the total energy consumption of the device **1**.
30 Configuration in regards of the total energy consumption of the device **1** means that the vacuum system **18** and the heating unit **5** are configured to regenerate liquid desiccant using minimum amount of energy and/or to regenerate liquid desiccant to obtain a predetermined ΔC or an optimal ΔC . A too low ΔC would result in a high

flow of liquid desiccant through the regeneration section **y** which in turn would result in a high energy consumption. A too high ΔC would result in inadequate water absorption in the water absorption section **a**. In the latter case, to absorb the same amount of water would then require a higher amount of energy, for example

5 by increased fan or pump **72** activity, and the device would probably not be as efficient in dry environments. The optimal ΔC , at which the device absorbs or produces the maximum amount of water per energy unit, depends on ambient temperature and relative humidity but also on the absorption material or salt used in the liquid desiccant. The configuration may be done according to the method of

10 the present invention. In general, by knowing ΔC or the predetermined value of concentration of the collected liquid desiccant in the liquid desiccant container **β** at which regeneration should be performed and a desired concentration of the regenerated liquid desiccant **S4** a first pressure **P1** in the container **3** generated by the vacuum system **18** may be selected in order to generate regenerated liquid

15 desiccant **S4** using a minimum amount of energy i.e. at or below a maximum energy. In one embodiment the temperature of the collected liquid desiccant **S2** or the liquid desiccant to be regenerated **S3** is preferably also measured, more preferably the ambient temperature and humidity is also measured. This configuration is preferably performed using a control unit **19** configured to obtain

20 or measure or determine the concentration and preferably also the temperature of the collected dispensed liquid desiccant **S2**, and/or preferably the concentration and preferably also the temperature of the liquid desiccant to be regenerated **S3** and preferably also the temperature and humidity (RH) of the surrounding atmosphere. In a preferred embodiment the control unit **19** uses the method

25 according to the present invention. In one embodiment the control unit is further configured to determine an energy amount required for regeneration of the liquid desiccant based at least on the predetermined value of concentration of liquid desiccant, i.e. the concentration when regeneration is to take place and the desired concentration of the regenerated liquid desiccant **S4** after regeneration, and

30 wherein the control unit is further configured to select the first pressure so that the energy amount is less than or equal to a maximum energy. In one embodiment the control unit is further configured to determine or select the desired concentration of the regenerated liquid desiccant **S4** based on at least one of an ambient temperature and an ambient humidity and the concentration of the collected

35 dispensed liquid desiccant **S2**. In another embodiment the control unit is

configured to select the first pressure to minimize a temperature difference between a third temperature and a first temperature. The minimization of the temperature is done so that the energy amount is still less than or equal to a maximum energy. The present invention facilitates that the concentration of the liquid desiccant to be dispensed **S1** at or very close to the saturation point.

The control unit **19** may be arranged in the device **1** to facilitate any communication between different parts or sections of the device **1**. The control unit **19** may be one or more units. The control unit **19** may be a computer or a processor with suitable software and may communicate with at least one sensor for detecting parameters such as concentration of liquid desiccant at different parts of the device, temperature of the liquid desiccant, ambient temperature and ambient humidity, among others. The communication between the vacuum system **18** and the heating unit **5** is schematically illustrated in figures 1-3, 5 and 6 with dotted lines and may be facilitated using control unit **19**. The control unit **19** is preferably configured to control the vacuum system **18** and the optional heating unit **5** to operate in an energy efficient way by using less than a maximum energy. The control unit **19** may preferably also communicate with the liquid desiccant container **β** to obtain or determine or detect or measure the temperature and/or concentration of the dispensed liquid desiccant **S2**. The control unit **19** preferably communicates with container **3** or the optional regenerated liquid desiccant container **21** in order to determine the obtained concentration of the regenerated liquid desiccant. Determinations and/or measurements may be done using suitable sensors in the relevant part or section which communicates with the control unit **19**.

Vapor compression

Evaporation of water is energy demanding and one way of reducing the energy needed is to use vapor compression where the vaporization energy is recovered. Suitable systems are for example mechanical vapor recompression or vacuum vapor compression systems. In one preferred embodiment the boiler **2** comprises a vacuum vapor compression (VVC) system or a mechanical vapor compression system (MVR) where said system comprises a heating unit **5** which heats the liquid desiccant in container **3** using compressed vapor obtained from the liquid desiccant.

Figure 1b) discloses a preferred embodiment wherein the boiler **2** comprises a heating unit **5** comprising a compressor **7**, a first desiccant heat exchanger **9** and a second desiccant heat exchanger **11**, a regulator **17a** and/or a valve **17b** and an optional heating device **28**. The optional heating device **28**, in thermal contact with the liquid desiccant in the container **3**, may act as a back-up heater if the heating unit **5** fails or during start-ups or just as an additional heater. The regulator **17a** regulates the pressure and pumps the liquid desiccant from the container **3** to the second heat exchanger **11** and back to the container **3**. The valve **17b** controls the flow and/or the pressure in the second desiccant heat exchanger **11**. The first desiccant heat exchanger **9** is operatively connected to the at least one liquid desiccant container **β** for delivery and receiving of liquid desiccant **S3** and **S4** respectively and further operatively connected to the container **3** for delivery and receiving of liquid desiccant **S3** and **S4** respectively. The first desiccant heat exchanger **9** is configured to heat exchange liquid desiccant to be regenerated **S3** (increasing the temperature from a first temperature **T1** to an elevated first temperature **T1'**) with regenerated liquid desiccant **S4** (decreasing the temperature from **T2** to a third temperature **T3**). The container **3** is operatively connected to the regulator **17a** for delivery of liquid desiccant where the regulator **17a** is further operatively connected to the second desiccant heat exchanger **11** for delivery of liquid desiccant **S3'**. The second desiccant heat exchanger is further operatively connected to the valve **17b** which in turn is operatively connected to the container **3** for delivery of liquid desiccant **S3'**. Container **3** is also operatively connected to the compressor **7** for delivery of vapor to the compressor. Compressor **7** is further operatively connected to the second desiccant heat exchanger **11** for delivery of compressed vapor. The container **3** is preferably operatively connected to a regenerated liquid desiccant container **21** for delivery of regenerated liquid desiccant **S4** where the regenerated liquid desiccant container **21** is further operatively connected to the liquid desiccant container **β**, preferably the liquid desiccant collecting part **46**, or the means for dispensing the liquid desiccant **66**. The regenerated liquid desiccant container **21** preferably communicates with the control unit **19**. When having more than one water absorption section **α** the regenerated liquid desiccant container **21** makes it easier and more efficient to distribute regenerated liquid desiccant to the different water absorption sections. One advantage of using vapor compression such as vacuum vapor compression (VVC) system or a mechanical vapor compression system (MVR) is that the

regeneration is energy efficient and can be optimized based on the absorption material.

The liquid desiccant to be regenerated **S3** having the first temperature **T1** enters the first desiccant heat exchanger **9** and is heated through heat exchange with regenerated liquid desiccant **S4**. The liquid desiccant **S3** exit the first desiccant heat exchanger **9** having an elevated temperature **T1'** and enters container **3**. In the container the pressure will be reduced using the vacuum system or compressor **7** and heated to a second temperature **T2** using heating system **5** and an optional heating device **28**. Liquid desiccant is allowed to exit the container and enter the regulator **17a** to adjust the pressure of the liquid desiccant prior to enter the second desiccant heat exchanger **11**. In the second desiccant heat exchanger the liquid desiccant is heat exchanged with the compressed vapor before re-entering the container **3**. Vapor **W1** from the liquid desiccant in the container **3** is produced by the heating and the reduced pressure and allowed to exit the container and enter the compressor **7**. The vapor is compressed in the compressor leading to a vapor **W1'** with increased temperature and allowed to enter the second desiccant heat exchanger **11** where the compressed vapor is heat exchanged with the liquid desiccant. The vapor is allowed to condense forming condensation **W4** in the heat exchanger. The compressor **7** and the second desiccant heat exchanger allows the condensation energy to be returned to the vaporization process. The compressor **7** is configured to compress the vapor so that the liquid desiccant **S3** in the container **3** has a temperature preferably within an optimum temperature range and/or an optimal desiccant concentration range when exiting the container **3**. This optimum temperature range and/or optimal desiccant concentration range is at least partly selected so that no or minimal amount of precipitation occurs in the first desiccant heat exchanger and/or during the transport of the regenerated liquid desiccant **S4** to the water absorption section **a** or the liquid desiccant container **β**. Regenerated liquid desiccant **S4** will only have a slightly higher salt concentration than the liquid desiccant to be regenerated **S3**. In one preferred embodiment the optimum temperature range is selected so that a minimum amount of added heat is needed to form vapor **W1** at the pressure **P1**.

Each container **3** of each boiler **2** comprises inlets and outlets for liquid desiccant to enter and exit the containers **3**. The inlets and outlets may be sealable.

Preferably the container **3** comprises a first inlet **30**, a first outlet **32** and optionally a discharge valve or pump **34**. The first inlet **30** is arranged to allow the liquid desiccant to be regenerated **S3** delivered from the liquid desiccant container **β** to enter the container **3**. The first outlet **32** of the container is arranged to allow concentrated liquid desiccant **S4** to exit the container **3** and to be delivered to the liquid desiccant collecting part **46** or to the means for dispensing the liquid desiccant **66** of the water absorption section **a**, but preferably the liquid desiccant collecting part **46**. The container **3** further comprises a second outlet **33** operatively connected to the compressor **7**, a third outlet **35** operatively connected to the regulator **17** and a second inlet **37** operatively connected to the second desiccant heat exchanger for receiving heated liquid desiccant **S3'**. The boiler **2** or the second desiccant heat exchanger **11** may have a water outlet **39** for withdrawal of condensed water **W4**. The boiler housing and/or the container **3** may further be thermally insulated in order to minimize energy losses.

15 Heat pump

In another preferred embodiment the heating unit **5** is a heat pump or a heat pump system **8**. Figure 1c) discloses another preferred embodiment where the boiler **2** comprises the container **3** having a heating chamber **4** and a condensing chamber **6**. The heating chamber and the condensing chambers are operatively connected to each other in such a way that vapor formed during heating of liquid desiccant in the heating chamber **4** may enter the condensing chamber **6**. One advantage of using a heat pump or a heat pump system is that it is energy efficient.

In one preferred embodiment the heating unit **5** comprises a heat pump system **8** having a first heat exchanger **10** arranged in the heating chamber **4** and a second heat exchanger **12** arranged in the condensing chamber **6**. The first heat exchanger **10** is in thermal contact with liquid desiccant in the heating chamber and the second heat exchanger **12** is in thermal contact with vapor entering the condensing chamber **6** from the heating chamber **4**. A cooling device **14** is connected to both the first heat exchanger and the second heat exchanger. The cooling device **14** cools the cooling media (**CM**) or refrigerant exiting the first heat exchanger **10** prior to entering the second heat exchanger **12**. A compressor **16** is operatively connected to the second heat exchanger **12** and the first heat exchanger **10** in order to compress the cooling media or refrigerant exiting the second heat exchanger prior

to entering the first heat exchanger. The heat pump system **8** in the boiler **2** is preferably configured to keep the liquid desiccant in the heating chamber **4** within an optimum temperature range and/or at an optimal concentration when exiting the boiler **3**. The container **3** is preferably operatively connected to a regenerated liquid desiccant container **21** for delivery of regenerated liquid desiccant **S4** where the regenerated liquid desiccant container **21** is further operatively connected to the liquid desiccant container **β**, preferably the liquid desiccant collecting part **46**, or the means for dispensing the liquid desiccant **66**. The regenerated liquid desiccant container **21** preferably communicates with the control unit **19**. When having more than one water absorption section **α** the regenerated liquid desiccant container **21** makes it easier and more efficient to distribute regenerated liquid desiccant to the different water absorption sections. In one preferred embodiment the optimum temperature range is selected so that a minimum amount of added heat is needed to form vapor **W1** at the pressure **P1**. Preferably the cooling device **14** and the compressor **16** are arranged on the outside of the container **3** of the boiler **2**.

In one embodiment the vacuum system **18** comprises an ejector or valve **22** operatively connected to the condensed water collector **20** and further connected to a water storage tank **24**. The water storage tank **24** is also operatively connected to a vacuum pump **26** which is further operatively connected to the ejector or valve **22**. This facilitates an efficient and easy way of collecting the condensed water.

An optional heating device **28** may be arranged in the heating chamber **4** in the boiler. The heating device is in thermal contact with the liquid desiccant to heat the liquid desiccant. The optional heating device **28** may act as a back-up heater if the heat pump system **8** fails or during start-ups or just as an additional heater.

By using a heat pump system as a heating device to heat the liquid desiccant in the heating chamber **4** the process can be even more optimized by selecting a cooling media that is well suited for the regenerating parameters (temperature and pressure) for the specific liquid desiccant.

A condensed water collector **20** may be arranged in the container **3**, preferably in the condensing chamber **6**, for collecting the condensed water when the vapor **W1** is condensed when brought into contact with the second heat exchanger **12**.

The first heat exchanger **10** in the heating chamber **4** is in thermal contact with the liquid desiccant configured to heat the liquid desiccant to produce vapor **W1** and the second heat exchanger **12** is arranged in the condensing chamber **6** configured to condensate the produced vapor **W1** that has entered or enter the condensing chamber. The cooling device **14** and the compressor **16** are arranged between the first and the second heat exchanger configured to cool the cooling media exiting the first heat exchange **10** and to heat the cooling media exiting the second heat exchanger **12**. An expansion valve **38** may be arranged in the heat pump system. The expansion valve **38** may be operatively connected to the cooling device **14** and also to the second heat exchanger, or it may be operatively connected to the cooling device **14** and also to the first heat exchanger **10**. The expansion valve **38** is preferably arranged downstream of the cooling device **14**. Suitable cooling media (**CM**) or refrigerant in the heat pump system **8** may be hydrofluoro carbons or mixtures thereof. Non-limiting examples of suitable cooling media are R407C, R134A and HFO-1234z. In one embodiment the cooling device **14**, the compressor **16** and the expansion valve **38** are all arranged outside of the container **3**.

The device **1** is then also configured to allow the collected water exiting the second outlet **36** of the container **3** to enter the water storage tank **24** via a first inlet **40**. The vacuum system **18** should preferably reduce the pressure in the container **3** of the boiler **2** as much as possible in order to limit the temperature difference between the liquid desiccant **S3** exiting the liquid desiccant collecting part **β** and the regenerated liquid desiccant **S4** exiting the regenerating section **γ**. This significantly reduces the amount of energy needed to heat the liquid desiccant in the boiler.

Referring now to figure 1b) and 2a)-b). Each container **3** of each boiler **2** comprises inlets and outlets for liquid desiccant to enter and exit the containers **3**. The inlets and outlets may be sealable. Preferably the container **3** comprises a first inlet **30**, a first outlet **32** and optionally a discharge valve or pump **34** operatively connected to the first outlet **32** or the first desiccant heat exchanger **9** for transporting regenerated liquid desiccant **S4** to the liquid desiccant container **β**. The first inlet **30** is arranged to allow the liquid desiccant to be regenerated **S3** delivered from the liquid desiccant container **β** to enter the container or the heating chamber **4** of the container **3**. The first outlet **32** of the container is arranged to allow concentrated

liquid desiccant **S4** to exit the container **3** or the heating chamber and to be delivered to the liquid desiccant collecting part **46** or to the means for dispensing the liquid desiccant **66** of the water absorption section **a**, but preferably the liquid desiccant collecting part **46**. The container **3** may also have a second outlet **36** for
5 withdrawal of condensed water collected using second desiccant heat exchanger **11** or the condensed water collector **20**. Boiler **2** and/or the container **3** may further be thermally insulated in order to minimize energy losses.

The device is thereby configured to allow the liquid desiccant to be regenerated **S3** exiting the liquid desiccant collecting container **β** to enter the boiler **2** and the
10 container **3** via first inlet **30**. The liquid desiccant is allowed to be heated in the container **3** of the boiler **2** by the heating unit **5** to generate vapor **W1** leaving a more concentrated liquid desiccant **S4**. The concentrated or regenerated liquid desiccant **S4** is allowed to exit the container **3** via first outlet **32** optionally via the discharge valve or pump **34**. The concentrated or regenerated liquid desiccant **S4** is
15 then returned to the means for dispensing liquid desiccant **66** or to the liquid desiccant collecting container **β** such as the liquid desiccant collecting part **46** or to the means for dispensing the liquid desiccant **66** of the water absorption section **a**, preferably via regenerated liquid desiccant container **21**. Vapor **W1** generated during the heating of the liquid desiccant in the container **3** is allowed to condense
20 and is collected.

The temperature of the liquid desiccant in the container **3** should be high enough to evaporate some of the water in the liquid desiccant. Since the pressure in the container **3** is reduced the evaporation or boiling temperature is reduced. The evaporation temperature is also dependent on the salt used and the concentration
25 of the salt in the liquid desiccant since salts increase said boiling temperature. In one preferred embodiment the temperature is the boiling temperature of the liquid desiccant at the first pressure in the boiler. In one preferred embodiment the optimum temperature of the liquid desiccant in the boiler or in the heating chamber is 30 to 125°C more preferably 70-115°C, or more preferably 75-110°C. This would
30 minimize the temperature difference between **T3** and **T1**. Small temperature differences will also result in no or only a small temperature increase of the liquid desiccant in the liquid desiccant collecting container **β**. In another preferred embodiment the optimum temperature is 90°C or lower, or 70°C or lower, or 60°C

or lower but 30°C or higher, or 40°C or higher. In a specifically preferred embodiment when the liquid desiccant is or comprises magnesium chloride the temperature is 30-60°C more preferably 40-50°C. The pressure in the container **3** is preferably 10-300mbar. In one embodiment when a heat pump is used the pressure in the container **3** is 30-100mbar, preferably 45-50mbar. In one embodiment when vapor compression is used the pressure is preferably 100-300mbar more preferably around 200mbar. The temperature of the liquid desiccant and the pressure in the container **3** should be optimized so that the device **1** is energy efficient. The pressure should preferably be low enough so that the liquid desiccant **S3** that enters the container **3** should have to be heated as little as possible in order to evaporate water from said desiccant. The difference between the first temperature **T1** and the third temperature **T3** should be as small as possible, preferably 5°C or less, or 3°C or less, or 1°C or less. Also the difference in concentration between **S3** and **S4** should preferably small.

15 The vacuum system **18** and the heating unit **5** are configured to generate a concentration, preferably an optimal concentration, of a regenerated liquid desiccant and the first pressure **P1** is preferably selected so that the temperature difference between **T3** and **T1** is also as small as possible. The vacuum system **18** and the heating unit **5** are preferably configured to evaporate just enough water so that the predetermined value of concentration is reached or exceeded when the regenerated liquid desiccant is mixed with the liquid desiccant in the liquid desiccant container **β**. The optimal concentration is preferably 1-30 weight% higher than the concentration of the liquid desiccant before the regeneration step. In one preferred embodiment the optimal concentration is 3-25 weight% higher. It is preferable to only remove sufficient amount of water in order to reach the predetermined value of concentration. A continuous removal would cost too much energy since the boiling point for the liquid desiccant increases with increasing concentration.

Any water generated in the regenerating section **γ** may exit through water outlet **39** or **42**. Water outlet **42** may be the second outlet **36** of the container **3** or it may be arranged in the water storage tank **24**. The water **W4** exiting the regenerating section **γ** may be collected, optionally further purified and used as drinking water or

used for cooling and moisturizing air in the air cooler according to the present invention.

- Referring now to figure 4a) and b). The liquid desiccant container **β** may be a liquid desiccant collecting part **46** arranged as a part of the water absorption section **α** and/or as a liquid desiccant storage tank **48** separated from the water adsorption section **α**. In one embodiment the liquid desiccant container **β** comprises a liquid desiccant collecting part **46** operatively connected to the water absorption section **α** and also operatively connected to a liquid desiccant storage tank **48**, for delivery of liquid desiccant to and from the water absorption section **α** and for delivery of liquid desiccant to the liquid desiccant storage tank **48**. The liquid desiccant collecting part **46** is preferably also operatively connected to the liquid desiccant regenerating section for delivery of regenerated liquid desiccant **S4**. The liquid desiccant collecting part **46** may be arranged at the bottom of the first housing **60** of the water absorption section **α**.
- Referring now to figure 4a) and b). Dispensed liquid desiccant **S2** that has absorbed water from the gas in the water absorption section **α** enters the liquid desiccant container **β** such as the liquid desiccant collecting part **46** or the liquid desiccant storage tank **48** for example via a first inlet **52**. Regenerated liquid desiccant **S4** may enter the liquid desiccant collecting part **46**. The device is configured to heat the liquid desiccant in the liquid desiccant collecting part **46** or the liquid desiccant storage tank **48** using the heater **50**. Liquid desiccant container **β** is operatively connected to the water absorption section **α** and the means for dispensing the liquid desiccant. Liquid desiccant to be dispensed **S1/S1'** to be transported to the water absorption section **α** may exit the liquid desiccant container **β** via a first outlet **56**.
- Liquid desiccant **S3** to be transported to the regenerating section **γ** may exit the liquid desiccant container **β** via a second outlet **58**. A sensor may be arranged in the liquid desiccant container **β** and adapted to determine the water content in the desiccant. The sensor is preferably communicating with the control unit **19** to efficiently control the temperature and concentration of the liquid desiccant.
- The heater **50** may be any suitable heater such as an electric heater, district heating, solar heating or any suitable thermal heater. In one embodiment the heater **50** is a heat exchanger. When the heater **50** is a heat exchanger the liquid desiccant in the container **β** may be heat exchanged with the cooling media or

refrigerant in the cooling device **14** of the heat pump system **8**. The latter is schematically illustrated in figure 3a) and b). The heater **50** and the cooling device **14** may be a heat exchanger such as a plate heat exchanger. By having a liquid desiccant storage tank **48**, which may be operatively connected to two or more liquid desiccant collecting parts **46**, a constant supply of liquid desiccant is facilitated, and furthermore, by heat exchanging the liquid desiccant in the container **β** with the cooling media in the heat pump system **8** the device **1** becomes more energy efficient. The liquid desiccant container **β** may be operatively connected to a pump **78** and a filter **81** wherein the filter is operatively connected to the water absorption section **α**. The filter **81** removes particles and other unwanted impurities. In one embodiment the liquid desiccant container **β** comprises a liquid desiccant collecting part **46** which is operatively connected to the pump **78** which in turn is operatively connected to the filter **81**. The filter is then operatively connected to the at least one means for dispensing a liquid desiccant **66** and wherein a pump **78** facilitates the transport of liquid desiccant.

In a preferred embodiment the device **1** contains two or more water absorption sections **α** per each liquid desiccant container **β** for example three or more, or four or more, or five or more. By having two or more water absorption sections the device **1** becomes more energy efficient and allows a more continuous absorbing and regeneration process. In another preferred embodiment the device **1** contains two or more water absorption sections **α** per each liquid desiccant regenerating sections **γ** for example three or more, or four or more, or five or more. This makes the device more efficient since the flow to and from the regenerating section **γ** is usually much lower than the recirculating flow of **S1/S1'**. Preferably when the device **1** comprises two or more liquid desiccant container **β** and/or two or more liquid desiccant regenerating sections **γ** the device further comprises at least one regenerated liquid desiccant container **21** operatively connected to each liquid desiccant regenerating section **γ**. Said regenerated liquid desiccant container **21** is preferably operatively connected to each water absorption section **α** for delivery of regenerated liquid desiccant **S4**. In a preferred embodiment the device is configured to mix the regenerated liquid desiccant **S4** with liquid desiccant to be dispensed **S1/S1'** upstream of the means for dispensing a liquid desiccant **66**.

- Referring now to figure 5a). The device **1** according to the present invention comprises a water absorption section **a**, a liquid desiccant container **β** and a liquid desiccant regenerating section **γ** where a gas is dried in the water absorption section **a** using a liquid desiccant which is collected in the liquid desiccant container **β** and regenerated in the regenerating section **γ** and then returned to the water absorption section **a** via the liquid desiccant container **β**. The water absorption section **a** comprises a first housing **60** with a first gas inlet **62** and a first gas outlet **64** and where said inlet and outlet may both be sealable using any suitable means to close or seal said inlet and outlet. The suitable means to close or seal the inlet or outlet may be valves, check valves, door, shutter or gate. The first housing **60** may be thermally insulated. The first housing **60** comprises at least one means for dispensing a liquid desiccant **66** and optionally means **68** for increasing the contact time and/or contact area between the gas and the liquid desiccant **S1**. The means **68** for increasing the contact time and contact area between the gas and the liquid desiccant may be arranged prior to the means for dispensing a liquid desiccant **66** in the gas flow direction or it may be arranged adjacent to or in contact with the means for dispensing the liquid desiccant. The liquid desiccant **S1** is usually a mixture of recycled or dispensed liquid desiccant from the liquid desiccant container **β** and the regenerated liquid desiccant **S4**.
- First housing **60** is operatively connected to the liquid desiccant container **β** allowing the dispensed liquid desiccant to exit the first housing **60** and enter the liquid desiccant container **β**. As described above the liquid desiccant container **β** may be a section or part of the first housing **60**, desiccant collecting part **46**, and/or it may be a separate tank, liquid desiccant storage tank **48**.
- The device **1** is configured to keep the regenerated liquid desiccant **S4** at a temperature at which the desiccant does not precipitate. In one embodiment the tubes or pipes are insulated in order to avoid or minimize precipitation. In another embodiment the liquid desiccant regenerating section **γ** is located close to the water absorption section **a**.
- The water absorption section **a** is arranged so that the incoming gas **A1** may flow from the first gas inlet **62** through the first housing **60** to and through the first gas outlet **64**. The gas should come into contact with the liquid desiccant **S1** using the means for dispensing liquid desiccant **66**. The means **68** for increasing the contact

time and contact area between the gas and the liquid desiccant may be in the form of baffles, particles or beads or a bed of particles or beads. The water or moisture in the gas **A1** is absorbed by the water absorption material in the liquid desiccant and the gas **A2** exiting through the outlet **64** is dry or at least drier than **A1** and has a
5 higher temperature than **A1** since the evaporation energy is released heating the gas. In order to avoid that liquid desiccant is carried away by the gas flow stream or as a final drying step a demister **70** may be arranged after the means for dispensing a liquid desiccant **66** and before the first gas outlet **64**.

10 In order to control the gas flow through the housing a fan or a pump **72** may be or is preferably arranged in the first housing **60**.

The means for dispensing the liquid desiccant **66** may be any suitable means and is in one preferred embodiment a spraying nozzle. In another preferred embodiment the means for dispensing the liquid desiccant **66** is a cooling pad or evaporator pad. When the means for dispensing the liquid desiccant is a cooling pad or evaporator
15 pad the pad is preferably arranged non-perpendicular to the gas flow. The liquid desiccant is provided at the top of the pad preferably using a distributor of suitable kind. Any suitably cooling pad or evaporator pad may be used such as CeLPad 0760 or CeLPad 0790 from Hutek. An advantage of using a cooling pad or evaporator pad is that the means **68** for increasing the contact time and contact
20 area is not necessary since the pad itself acts as such mean **68** and the pads reduces the amount of liquid desiccant needed and are efficient for water adsorption using a liquid desiccant.

In one preferred embodiment the means for dispensing the liquid desiccant in the first housing **60** is a cooling or evaporator pad or pads **66**. These pads provide a
25 large surface to be exposed for the air flow and makes it easy and efficient to distribute the liquid desiccant. The cooling or evaporator pad has a front and a back side where the front side faces the incoming gas. Preferably the pads **66** are arranged at an angle X° with respect to an axis **a**, said axis **a** extending essentially in the direction of the gas flow **A1**. In one embodiment two pads **66** are preferably
30 arranged together in a v formation as shown in Figure 5b) and c) with the opening of the v facing the direction of the gas flow. Preferably, the pads **66** are arranged symmetrically about the axis **a**, so that the opening of the v is two times the angle X° . The angle X° between the pads **66** in the first housing **60** is preferably 10° or

more, or 20° or more, or 30° or more but 80° or lower, or 70° or lower, or 60° or lower to the axis **a**. In one preferred embodiment the angle is 30-40°. This arrangement of the pads in v formation provides a large surface area and good water absorption. Figure 5d) discloses another embodiment where a single cooling pad is arranged at an angle X° with respect to the axis **a** and extends across the direction of the gas flow **A1** from one side of the first housing **60** to the other side of said housing in order to force the gas to pass through the pad. The angle X° is preferably 10-40° such as 20-30° in order to obtain good absorption and a good air flow.

10 In order to further control and optimize the gas flow through the pads, protruding elements **67** may be arranged along the pads, preferably at an angle with respect to the pad, said angle not being 90° so that the elements **67** are not perpendicular to the pad i.e. at an angle less than 90° such as 80° or lower. In one preferred embodiment the protruding elements **67** are arranged on back side of the cooling or

15 evaporator pad **66**. The protruding elements preferably have a concave shape in the direction of the gas flow to further optimize the flow through the pads. This is schematically illustrated in Figure 5b). In another preferred embodiment the protruding elements have a convex shape in the direction of the gas flow to further optimize the flow through the pads. In a preferred embodiment the angle X° of the

20 cooling pads or evaporator pads is 30-60°C and each pad of this embodiment preferably comprises protruding elements **67** which are arranged essentially non-perpendicular to the pads. In figure 5c) a preferred embodiment is disclosed where the pads **66** are arranged at an angle X to the axis **a** and where the proximal ends of the pads or pad **66** in the direction of the gas air flow **A1** are separated from the

25 walls of the first housing **60** by a distance **b**. This distance **b** is dependent on the size of the first housing but may be in the range of 10-100cm. By creating a distance **b** between the pads and the wall of the first housing the incoming air **A1** may more easily flow through the pads. The distance **b** may be created by arranging a separating wall **61** between the wall of the first housing **60** and the pads **66**. In

30 one embodiment the distal ends of the pads may also be separated by separating device **69** which may further enhance the flow and reduce the load on the fan or pump **72**. In a preferred embodiment the pads **66** extends from a distal end of the first housing **60** to a proximal end of the first housing **66** in order to obtain an optimal surface area and uptake of moisture.

The liquid desiccant may be recirculated until the water absorption material is saturated or has reached the predetermined value of concentration. Prior to being dispensed the liquid desiccant may be cooled using a cooling device **74** operatively connected to the liquid desiccant collecting container **β** for receiving of liquid desiccant (**S1/S1'**) and optionally also operatively connected to the regenerating section **γ** for receiving regenerated liquid desiccant **S4**. The cooling device **74** is also operatively connected to the means for dispensing a liquid desiccant **66** for delivery of cooled liquid desiccant.

New or fresh liquid desiccant is supplied using a liquid desiccant supplying device **76**, which may be a storage container and a pump, configured to supply the liquid desiccant. The supplying device **76** may communicate with the control unit **19** in order to monitor the need for new or fresh liquid desiccant. The supplying device **76** may be communicating with the boiler **2**. New, fresh, recirculated or regenerated liquid desiccant may be cooled to a desired temperature using the cooling device **74**. The cooling device may be, but is not restricted to, a fan and a heat exchanger, a sorption cooling device or a heat pump. By lowering the temperature of the recirculated liquid desiccant, or the regenerated desiccant, the desiccant may obtain a temperature lower than the ambient air. This would make the device an efficient cooling and dehumidifying device.

The device **1** comprises at least one pump **78** configured to facilitate a flow of the liquid desiccant from the water absorption section **α**, to the liquid desiccant container **β**, to the boiler **2** and the container **3** and out of the container **3** and to the means for dispensing the liquid desiccant **66**. The number of pumps should be as many as necessary to facilitate said flow such as one, two, three, four, five or six or more. In one embodiment the device according to the present invention comprises at least two pumps.

The pumps used in the present invention may be arranged at any suitable position in the device. In one embodiment the pump may be one or more of a centrifugal pump, linear pump, diaphragm pump, piston pump or a rotary vane pump. The selection of pump or pumps is dependent on the wanted pressure. The COP value (Coefficient of Performance) should be as high as possible.

The liquid desiccant may be any solution that may absorb water from a gas or air. The solution contains any suitable absorption material or salt where the absorption material or salt may be LiCl, CaCl₂, CaBr₂, LiBr₂, MgCl₂, NaNO₃, an alkali acetate (preferably potassium acetate), sulphates or any suitable material known to a person skilled in the art or combinations thereof. In one embodiment the liquid desiccant contains potassium acetate, LiCl, CaCl₂ or MgCl₂, preferably LiCl or MgCl₂ more preferably MgCl₂ (magnesium chloride) or more preferably potassium acetate. The advantage of magnesium chloride is that a liquid desiccant containing it absorbs water to a high extent, it has a low reactivity, has a low toxicity, is cheap and it does not increase the boiling temperature of the water in the liquid desiccant significantly. In one embodiment the liquid desiccant contains potassium acetate. The advantage of using alkali acetate such as potassium acetate is that it absorbs water to a high extent but is not corrosive. The absorption material may be in the form of salt, particles or powder. The concentration of the absorption material in the liquid desiccant is preferably near saturated, saturated or over saturated in order to obtain higher absorption. In one embodiment the liquid desiccant is saturated or over saturated with the absorption material.

The present invention facilitates that a much higher salt concentration in the liquid desiccant may be used which in turn allows more moisture to be absorbed. The salt concentration in the liquid desiccant to be dispensed **S1** using means **66** is preferably as high as possible in order to absorb as much moisture as possible. In one embodiment the salt concentration is near or at the saturation point or the liquid desiccant is over saturated. In one embodiment the concentration is at least 30weight% (wt%), or at least 32weight% or at least 35 weight%. In one preferred embodiment the salt concentration is 30-50wt% preferably 33-46wt%. In another preferred embodiment when the salt is or comprises magnesium chloride the concentration is 30weight%, at least 33wt%, or at least 34wt%, or at least 35wt% such as 33-35wt% or 34-35wt%. In another embodiment when the salt is lithium bromide (LiBr₂) the concentration is preferably 40-50 wt% more preferably 43-47 weight% even more preferably 45-46 weight%. In another embodiment the concentration of alkali acetate in the liquid desiccant to be dispensed **S1** is at least 65 weight%, preferably 67-70weight%.

The present invention is proven to be very efficient especially in environments with a relative humidity (RH) of 70% or lower, such as 65% or lower, or 60% or lower, or 55% or lower, or 50% or lower.

The advantage of the present invention is illustrated in Figure 9a) and b) where a
5 higher concentration in the slurry is possible in comparison with prior art and this is achieved in an energy efficient manner.

An air cooler

Referring now to figure 6. The device may be used as an air cooler **79**. The air cooler comprises the device for absorbing water from gas **1** and a humidifier **1**. The
10 humidifier **1**, sorption cooler, comprises a second housing **80** operatively connected to the water absorption section **a** for receiving air. The second housing **80** has a first inlet **82** operatively connected to the water absorption section **a** and a first outlet **84**, at least one means for dispensing an aqueous solution **86**, optionally means **88** for increasing the contact time and contact area between the gas and the
15 aqueous solution **W2** (for example water) and which may be arranged prior to or adjacent to the means for dispensing water **86** in the gas flow direction. The first inlet **82** and the first outlet **84** may both be sealable. The means for dispensing water **86** is preferably arranged so that the dispensing of water is done essentially in the direction of the gas flow or in a parallel direction to the gas flow. The means
20 **86** may comprise a mouthpiece or nozzle with openings or outlets in the direction of the gas flow or the means **88** may be cooling pads or evaporator pads. The humidifier or cooling section **1** further comprises a water collecting part **90** which is operatively connected to the means for dispensing water and preferably also the water outlet **42**. A third heat exchanger **92** may be arranged prior to the first inlet
25 **82** in the direction of the gas flow and the second housing **80** may also comprise a demister **94** arranged after the means for dispensing water and prior to the first outlet **84**. The water collecting part **90** may be a separable part from the housing **90** or it may be an inseparable part of the housing **80**. The collecting part **90** may be made of the same material as the second housing **90** or it may be made of
30 another material. In one embodiment the water collecting part **90** and the water storage tank **24** are the same.

The air cooler **79** according to the present invention may comprise at least one pump **96** configured to facilitate that the water or aqueous solution is transported from the second housing **80** to the water collecting part **90** and to the means for dispensing water **86**. The number of pumps should be as many as necessary to
5 facilitate said transportation. The number of pumps may be one, two, three, four, five or six or more. In one embodiment the device according to the present invention comprises at least two pumps.

The third heat exchanger **92** communicates with the first gas outlet **64** of the first housing so that the gas **A2** exiting the first housing through the first gas outlet **64**
10 is cooled in the third heat exchanger **92** to provide a gas **A3**. The gas **A3** is humidified by the aqueous solution **W2** and the temperature of the exiting gas **A4** is also lower than the gas **A3** since the evaporation energy is absorbed cooling the gas. The water collected at the water collecting part **90** may be reused as the aqueous solution **W3**. A cooling device **75** may be arranged in the humidifier configured to
15 cool the water to be dispensed using the means for dispensing an aqueous solution **86**. New or fresh water is supplied using a water supplying device **98** configured to supply water or aqueous solution and communicates with the means for dispensing aqueous solution **86** optionally via the cooling device **60** or the water collecting part **90**. The supplying device **98** is preferably communicating with the control unit **19**
20 in order to monitor the quality of the water and the need for new or fresh water. The water supplying device **98** may be a storage container and a pump. A sensor may be arranged in the water collecting part **90** and said sensor may communicate with the control unit **19**.

When the water vapor from the gas is absorbed by the desiccant, the vaporization
25 heat is released in the phase transition from vapor to water. The means for dispensing the desiccant **66** and the flow of the desiccant is arranged such that heat of vaporization and water from the gas is transferred away from the first housing **60** by the desiccant, for example by dispensing the liquid desiccant essentially vertically while the gas flow is essentially horizontal. When the gas and
30 the desiccant have the same vapor pressure, the desiccant will not absorb any more water vapor. However, if there is a temperature difference between the two media, heat energy will still be exchanged between the gas and the desiccant. Hence, the temperature and the vapor pressure of the gas or air exiting the first gas outlet **64**

might be the same as that of the liquid desiccant before being entering into the first housing **60**. Hence, the temperature of the gas might be lower and the humidity content of the gas might be lower than the gas entering the housing. This is even more pronounced when the gas flow through the first and/or the second housing is horizontal.

The dehumidified gas or air entering the humidifier might have the same vapor pressure and temperature as the desiccant, and therefore a low relative humidity. A low relative humidity will allow the gas to be cooled through sorption cooling, i.e. humidification. Sorption cooling, or humidification, of the gas is here made through any means known to a person skilled in the art herein denoted means for dispensing water **86**. The water used for the sorption cooling might be but is not restricted to, taken from the water collecting part **90**. Since the gas leaving the water absorption or dehumidification section **a** will have the same or similar temperature as the liquid desiccant and the water used for sorption cooling should preferably have the same or more preferably lower temperature than the gas the water used may be lead through the cooling device **60**.

The device **1** or **79** may further comprise regulators in order to control the flow of the liquid desiccant and water, and to regulate the pressure in the pipes. There may also be an expansion tank or a regulator **100** that is operatively connected to the liquid desiccant regeneration system **y** and also operatively connected to the water absorption section **a**. In the expansion tank or a regulator **100** the pressure of the liquid desiccant is regulated preferably to around ambient pressure.

The different parts (first housing, pumps, containers and boiler for example) of the device are connected via suitable tubing. The tubing should preferably be insulated in order to reduce the risk of precipitation in the liquid desiccant, minimize energy losses and to avoid condensation in the tubing. In one embodiment any tubing for liquid desiccant is insulated.

The device **1** and **79** may comprise a control unit **19** configured to optimize the energy and the amount of water extracted from the gas and the properties for regenerating the liquid desiccant. The control unit may control the pressure of the at least one pump **78** and **96**, the amount of heat added by the optional heating device **28** to the liquid desiccant in the heating chamber **4**. The control unit may

also control any restrictor and may monitor the concentrations of the liquid desiccant in the liquid desiccant container **β**. The control unit **19** may comprise one or more sensors arranged in the device. The control unit preferably comprises a suitable software in order to adjust the settings or properties of the different parts of the device.

The different sections **α**, **β**, **γ** and **λ** may be arranged in a common housing or separately. Sections **α** and **λ** are herein described as different sections but may be just one section where the first gas outlet **64** of the first housing **60** and the first inlet **82** of the second housing **80** are the same.

10 The method of absorbing water and cooling air

The method and the flow of the gas and liquids according to the present invention will now be described with reference to figure 7 and 8. In the following description and figures the denoted gas flows (**A1-A4**) and liquid desiccants (**S1-S4**) should only be seen as illustrative and not limiting.

15 Referring now to figure 7. A gas flow **A1** is allowed to enter the first housing **120**. A liquid desiccant **S1** is dispensed **122** and the gas flow **A1** is brought into contact with the liquid desiccant and the optional means **68** for increasing the contact time and contact area between the gas and the liquid desiccant. Water or moisture is allowed to be absorbed by the water absorption material in the liquid desiccant

20 **124**. The liquid desiccant that has been brought into contact with the gas flow **S2** is then collected **126** and the gas flow **A2** is allowed to exit the first housing **60 128**. The liquid desiccant **S2** is allowed to exit the first housing and collected **130** in the liquid desiccant container **β** and optionally heated **132** using heater **50**. The heated liquid desiccant **S3** exiting the liquid desiccant container **β** is collected in the boiler

25 **2 134**.

Water is evaporated from the collected liquid desiccant **136** using the heat pump system **8** and the evaporated water is condensed **138** forming condensed water which is collected **140**. The cooling media or refrigerant in the heat pump system may be heat exchanged **142** with the liquid desiccant in the liquid desiccant

30 container **β**. A concentrated liquid desiccant **S4** is allowed to exit **144** the boiler **2** and is returned **146** to the liquid desiccant container **β** or the water absorption

section **a**. Liquid desiccant in the liquid desiccant container **β** may then be transported to the means for dispensing the liquid desiccant **148**.

When the device is used to produce humidified cool gas or air the method further comprises the steps illustrated in figure 8. The dried gas **A2** exiting the first housing **60** is provided **150** and may then be heat exchanged **152** forming a cooled gas **A3**. In one embodiment the media used in the heat exchanger is the surrounding air or gas such as **A1**. In one embodiment the aqueous solution is cooled prior to being dispensed using a cooling device **75**. An aqueous solution or water **W2** is dispensed **154** and the gas flow **A3** is brought into contact with the aqueous solution and the optional means **88** for increasing the contact time and contact area between the gas and the aqueous solution or water **156**. The aqueous solution that has been in contact with the gas flow is then collected **158** in the water collecting part **90**. The gas is humidified when brought into contact with the dispensed solution and the evaporation energy is absorbed cooling the gas and the cooled humidified gas **A4** exits **160** the second housing. The collected water in the water collecting part **90** is allowed to be transported **162** to the means for dispensing water **86**. Optionally the water **W4** generated in the liquid desiccant regeneration process and collected in step **140** may be returned **162** to the water collecting part **90**.

A preferred embodiment of a method for controlling a device for absorbing water will now be described in more detail.

During operation of the device **1**, concentration of liquid desiccant is detected, either at suitable intervals or continuously. The detection can take place in the liquid desiccant container **β** or in any conduit that conveys liquid desiccant to and from the water absorption section **a** as well as in the water absorption section **a** itself. Preferably, a first sensor is arranged inside the liquid desiccant storage tank **48**, at an inlet or outlet of the liquid desiccant storage tank **48** or in the liquid desiccant collecting part **46** or inside a pipe, tube or other conduit that transports liquid desiccant in the device **1**. The first sensor is preferably configured to determine the water content in the desiccant, as also described above, or to determine the concentration directly or by measuring the conductivity and temperature, and can communicate measurement values to the control unit **19** where the concentration can be determined and monitored as mentioned above.

Preferably measurements, calculations or determinations conducted by the control unit **19** is based on what absorption material or salt is used in the liquid desiccant.

When using the term concentration of liquid desiccant herein, this is to be understood as a concentration of an absorption material or salt in the liquid desiccant. In some embodiments the salt is magnesium chloride (MgCl_2) but in other embodiments the salt could instead be potassium chloride (KCl), an alkali acetate or lithium bromide (LiBr) or any other suitable salt. The water content or the concentration of salt is determined and compared to the predetermined value which depends on the salt used and the environment in which the device **1** is operating. Dependent on the temperature and humidity of the environment and the gas to be dehumidified the predetermined value varies. In order to absorb moisture from a gas having a relative humidity (RH) of 50% or lower the concentration of the salt in the liquid desiccant to be dispensed is required to be close to saturation. For some salts such as magnesium chloride this would mean a concentration of preferably at least 30%, or at least 31%, or at least 32%, or at least 33%, or at least 34%, or at least 35%. A preferred range is 34-36 weight%. When using potassium acetate the concentration is preferably at least 65weight%, more preferably at least 67 weight%, preferably at least 69weight%. A preferred range is 67-70 weight%.

When the detected concentration of the collected liquid desiccant **S2** is determined to be at or below the predetermined value, a selected quantity of liquid desiccant is transported to the liquid desiccant regenerating section **y** as described in detail above. The quantity of liquid desiccant is preferably less than 0.25 of a total amount (weight) of liquid desiccant in the device **1**, preferably less than 0.1 of the total amount and more preferably less than 0.05 but preferably more than 0.001 of the total amount. Thereby, the device **1** can continue operation absorbing water using remaining liquid desiccant.

Preferably, after the selected quantity of liquid desiccant has been removed for regeneration the concentration is measured again after an interval or continuously, and as long as the concentration is determined to be at or below the predetermined value another quantity is selected and transported to the regenerating section **y** for regeneration. The selected quantity can remain fixed during operation of the device **1** or can vary depending on the total amount of liquid desiccant in the system or on how much the detected concentration differs from the predetermined value, where a

large difference would indicate that a larger quantity should be selected for regeneration whereas a small difference would instead indicate that only a smaller quantity needs to be regenerated in order to maintain the concentration at a desired value or in a desired interval.

- 5 The liquid desiccant **S3** that is transported for regeneration is at a first temperature **T1**, that can be determined by a temperature sensor or similar means for measuring temperature and that can be arranged inside a tube, pipe or conduit that transports the liquid desiccant **S3** to the liquid desiccant regeneration section **y**, inside an inlet or outlet of such a tube, pipe or conduit, or alternatively in the
- 10 same or similar location where the first sensor is placed. Alternatively, the temperature sensor can be identical with the first sensor and be configured to detect both concentration and temperature.

- Inside the liquid desiccant regeneration section **y**, the liquid desiccant is regenerated as described in detail above. The regeneration is performed at the
- 15 second temperature **T2** which is the boiling temperature of the liquid desiccant, and at a first pressure. By adjusting the first pressure, the boiling temperature can be correspondingly altered as is well known within the art. As non-limiting examples the concentration of the absorbing material or water absorbing material such as magnesium chloride of the liquid desiccant increases from around 30-33
- 20 weight% to around 34-36 weight% during the regeneration, and for alkali acetate such as potassium acetate the concentration increases from 60-65 weight% to 66-70 weight% during the regeneration. The regeneration takes place until the liquid desiccant reaches the desired concentration that may be preset or may be determined by the device **1** or control unit **19** of the device depending on
- 25 parameters such as ambient temperature, ambient humidity, or parameters of the device **1** such as a total amount of liquid desiccant in the water absorption section and/or the liquid desiccant container. The desired concentration of the regenerated liquid desiccant may advantageously be the optimal concentration, i.e. the concentration that makes the concentration of the liquid desiccant obtained after
- 30 mixing the regenerated liquid desiccant and the liquid desiccant in the liquid desiccant container **β** at least reach the predetermined value of concentration where regeneration is to take place so that no further regeneration is needed. In one embodiment the desired concentration may advantageously be the concentration at

which an optimal ΔC is obtained. In some applications, regeneration may be set to take place when the predetermined value is reached and the optimal concentration should then be a concentration that brings the concentration of the total amount of liquid desiccant in the liquid desiccant container above the predetermined

5 concentration. In other applications, regeneration may be set to take place when the concentration is below the predetermined concentration, making the optimal concentration that which brings the concentration of the total amount of liquid desiccant in the liquid desiccant container to the predetermined amount or above.

After regeneration, the regenerated liquid desiccant **S4** is transported to be used

10 again for absorbing water, either by insertion of the regenerated liquid desiccant **S4** into the water absorption section **a** or by insertion into the liquid desiccant container **β**. In some embodiments, the regenerated liquid desiccant **S4** is used directly for absorbing water but in most embodiments it will first be mixed with liquid desiccant that is already in the water absorption section **a** or the liquid

15 desiccant container **β** preferably with the liquid desiccant in the liquid desiccant collecting part **46**. The regenerated liquid desiccant **S4** exiting the liquid desiccant regenerating section **γ** has a third temperature **T3**.

The regeneration takes place using a first energy amount that is required to set and maintain the pressure inside the liquid desiccant regenerating section. This energy

20 is needed to operate the vacuum system that is configured to adjust the pressure. In order for the regeneration to be performed in an energy efficient way, a maximum energy is determined or preset and the first pressure **P1** is selected in such a way that the first energy amount is less than or equal to the maximum energy. The regeneration takes place until the liquid desiccant is at the desired concentration

25 and/or a difference between the third temperature (**T3**) and the first temperature (**T1**) is minimized. Advantageously, the regeneration is performed in such a way that the desired concentration is achieved with a minimum of increase in temperature while still requiring less than or equal to the maximum energy.

It is thus advantageous to keep the third temperature **T3** as low as possible so that

30 the difference between the third temperature **T3** and the first temperature **T1** is minimized. Thereby, the efficiency of the water absorption can be increased and the need for further cooling of the regenerated liquid desiccant **S4** can also be decreased, thus also saving energy. Since the third temperature **T3** is reached

- starting from the first temperature **T1** and raising the first temperature **T1** to the boiling temperature for the liquid desiccant, the third temperature **T3** can be minimized by decreasing the boiling temperature of the liquid desiccant in the regenerating section **γ**. This is achieved by selecting the first pressure **P1** so that
- 5 the boiling temperature is lowered. The control unit **19** is preferably arranged to use the first temperature **T1** to determine a suitable first pressure **P1** in order to keep the second temperature **T2** close to the first temperature but at the same time avoiding lowering the pressure too much requiring excessive energy consumption. In the preferred embodiment, the first pressure **P1** is selected so that the energy
- 10 required to lower the pressure is balanced against the energy that would be required to cool the regenerated liquid desiccant **S4** from the third temperature **T3** to the first temperature **T1**. In this preferred embodiment, the first pressure **P1** is therefore selected as the lowest pressure that still require less energy than the cooling of the regenerated liquid desiccant **S4**.
- 15 Generally, the third temperature **T3** will be the same as the second temperature **T2** or at least very close to the second temperature **T2**, if no significant heating of the liquid desiccant takes place after regeneration. It is also advantageous to avoid heating of the liquid desiccant after regeneration, since this aids in keeping the difference between the third temperature **T3** and the first temperature **T1** to a
- 20 minimum. If the regenerated liquid desiccant is heat exchanged with liquid desiccant to be regenerated the third temperature **T3** will be lower than the second temperature **T2**. However it is preferred that **T3** is high enough in order to avoid precipitation in the heat exchanger.
- Thus, preferably the first temperature **T1** is used to select the first pressure **P1** so
- 25 that the boiling temperature is as close to the first temperature **T1** as possible, while still keeping the energy required to create the first pressure **P1** below an energy threshold that is predetermined or that can be adjusted depending on the energy required to cool the regenerated liquid desiccant, or alternatively adjusted depending on available energy or on any other factor deemed suitable.
- 30 Thus, by determining the concentration of liquid desiccant before regeneration and by selecting a desired concentration after regeneration, the energy requirements for performing the regeneration at different boiling temperatures can also be determined. Then, a boiling temperature is selected that is as low as possible while

also requiring energy below that maximum energy value so that the temperature difference is minimized in an energy efficient and thereby cost efficient way. Depending on the concentration of the liquid desiccant before regeneration and the desired concentration after regeneration, as well as other factors such as the temperature before regeneration the energy requirements may differ as will be readily apparent to the skilled person.

The desired concentration of liquid desiccant can be selected or predetermined, or can alternatively be determined based on an ambient temperature, an ambient humidity and/or other factors such as a total amount of liquid desiccant. In applications where the ambient temperature and ambient humidity are both high, a lower desired concentration can be used whereas a low ambient temperature and a low ambient humidity would require a higher desired concentration in order for the device to operate efficiently to absorb water. In some applications, at least one parameter such as an ambient temperature, ambient humidity or other factors can be determined during operation and the desired concentration also adjusted during operation to allow for an efficient operation even where temperature, humidity and/or other factors change over time. However, in many applications the desired concentration can be predetermined an preset in order to achieve a cost efficient device with fewer sensors and other components.

In some embodiments, it can still be needed to cool the regenerated liquid desiccant **S4** from the third temperature **T3** to the first temperature **T1** or at least to a temperature lower than the third temperature **T3**. This need can also be determined by the control unit **19** depending on the third temperature **T3** or other factors. In some embodiments, it is desirable to cool the regenerated liquid desiccant **S4** further, preferably to an ambient temperature or even lower since this increases the water absorption efficiency.

During transport of the liquid desiccant **S3** to the liquid desiccant regenerating section **γ** and of regenerated liquid desiccant **S4** back to the water absorption section **α** or the liquid desiccant container **β**, it is advantageous to avoid or at least to minimize precipitation of the salt in the liquid desiccant. This is achieved by transporting the liquid desiccant at a pressure that is above a second pressure **P2** and/or at a temperature that is above a fourth temperature **T4**. In one preferred embodiment **T4** is the same as **T3**.

In one embodiment, the first temperature **T1** is 25°C and the first pressure **P1** is selected as 50 mbar. This will result in a second temperature **T2** that is also the boiling temperature of the liquid desiccant that is in the range of 40-45°C. When additional heating of the liquid desiccant after regeneration is avoided, the resulting
5 third temperature **T3** is essentially the same as the second temperature **T2**, i.e. no additional heating is performed that would alter the temperature significantly. In this embodiment, the device may be located in a place having an ambient temperature of about 20°C or about 30°C, and the salt used in the liquid desiccant is MgCl₂. The difference in temperature between the liquid desiccant before
10 regeneration and the liquid desiccant after regeneration is about 15-20°C but in many embodiments smaller differences can be achieved, especially when a lower pressure is selected as the first pressure **P1**. A lower concentration of salt might be used in environments with high humidity.

As described above, heat may advantageously be transferred from the liquid
15 desiccant after regeneration to the liquid desiccant that is about to be regenerated, so that the increase in temperature during regeneration can further be minimized. In such embodiments, the difference in temperature can be kept very small while at the same time allowing for a higher first pressure **P1** that can be achieved using less energy.

20 The concentration of liquid desiccant selected as the predetermined value varies depending on each application of the present invention, but some important factors for selecting the concentration are an ambient humidity and flow in the device. For a higher ambient humidity a lower concentration such as about 30% (when using magnesium chloride or lithium chloride for example) can be selected while a higher
25 concentration such as about 33%, 34% or even 35% may be required when the ambient temperature and ambient humidity is lower. When using alkali acetate such as potassium acetate the corresponding concentrations are 60-65 weigh% at high ambient humidity and 67-70 weigh% at low ambient humidity. For a high flow in the device, a higher concentration may be preferred while at a lower flow a lower
30 concentration can be selected. The concentrations given here are for an embodiment where MgCl₂ is used in the liquid desiccant, and for other salts the selected concentrations will vary as readily understood by the skilled person. However, the general principle of selecting the concentration depending on the flow

and the ambient humidity is the same regardless of the substance used as liquid desiccant.

- Although embodiments of the invention described above comprise a local control unit and a control unit **19**, and processes performed in at least one processor in that control unit **19** or alternatively a separate processor unit, the invention also extends to computer programs, particularly computer programs on or in a carrier, adapted for putting the invention into practice. The programs may be in the form of source code, object code, a code intermediate source and object code such as in partially compiled form, comprise software or firmware, or in any other form suitable for use in the implementation of the process according to the invention. The program may either be a part of an operating system, or be a separate application. The carrier may be any entity or device capable of carrying the program. For example, the carrier may comprise a storage medium, such as a Flash memory, a ROM (Read Only Memory), for example a DVD (Digital Video/Versatile Disk), a CD (Compact Disc) or a semiconductor ROM, an EPROM (Erasable Programmable Read-Only Memory), an EEPROM (Electrically Erasable Programmable Read-only Memory), or a magnetic recording medium, for example a floppy disc or hard disc. Further, the carrier may be a transmissible carrier such as an electrical or optical signal which may be conveyed via electrical or optical cable or by radio or by other means. When the program is embodied in a signal which may be conveyed directly by a cable or other device or means, the carrier may be constituted by such cable or device or means. Alternatively, the carrier may be an integrated circuit in which the program is embedded, the integrated circuit being adapted for performing, or for use in the performance of, the relevant processes.
- 25 In one or more embodiments, there may be provided a computer program loadable into a memory communicatively connected or coupled to at least one data processor, e.g. the control unit **19**, comprising software or hardware for executing the method according any of the embodiments herein when the program is run on the at least one data processor.
- 30 In one or more further embodiment, there may be provided a processor-readable medium, having a program recorded thereon, where the program is to make at least one data processor, e.g. the control unit **19**, execute the method according to of any

of the embodiments herein when the program is loaded into the at least one data processor.

It is to be noted that features of the various embodiments described herein may freely be combined unless such a combination is expressly stated as unsuitable.

5 EXAMPLES

Example 1

If the temperature of the desiccant entering the heat exchanger is about 20 C the maximum allowed concentration of magnesium chloride is about 35 % to avoid formation of salt crystals in the heat exchanger since the warm desiccant will be cold. Since water is removed from the desiccant in the evaporation process, the concentration of the desiccant entering the heat exchanger and the evaporation process needs to be lower than 35%.

If a certain water production capacity is desired, $\dot{m}$, then flow, Q , through the heat exchanger and the evaporator depends on the difference in concentration, ΔC , before and after the evaporation process according to

$$Q = \frac{\dot{m}}{\Delta C}$$

Since there are no perfect heat exchangers with 100 % efficiency the higher the flow, Q , the more energy is needed to heat the liquid desiccant to the boiling point. The power, P , needed to heat the desiccant to the boiling point can be expressed as

$$20 \quad P = C_v Q (T_b - T_a) (1 - \mu)$$

where Q is the flow through the desiccant, T_b is the boiling temperature, T_a is the temperature on the desiccant in the water absorber, and μ is the efficiency on the heat exchanger. From the equation, it can be seen than is desirable to minimize the flow and maximize the efficiency μ . This is schematically illustrated in figure 9b.

25 As an example, if ΔC is 5. An efficient evaporation process might be possible using mechanical vapor recompression. However, the concentration during water absorption can not exceed 30 % which corresponds to an equilibrium relative humidity of about 50 %. The impact of this is that in a water absorption process the

air can only be dried to 50 % in relative humidity. If the air is drier than 50 % in relative humidity, it is not possible to absorb water vapor from the air. Moreover, the if a fan is used to the process the energy requirement to absorb 1 kg of water vapor from the air depends on the relative humidity in the air to be treated. If the
5 air to be treated, the process air, is for example 51 %, the fan needs to treat a large air volume to absorb 1 kg of water. If the process air is 90 %, the air volume to be treated is less.

Example 2

A device according to the present invention was used to absorb water from air. As
10 liquid desiccant magnesium chloride was used and cooling pads was used to distribute the liquid desiccant. A fan was arranged to transport air through the water absorption section and the air had a relative humidity of 58%.

The experiment showed that the relative humidity of the air after absorption was 43%.

15 Example 3

A commercially available boiler using a heat pump was used to study how the concentration of the liquid desiccant affects the energy consumption (kWh) when evaporating 1 liter of water. Magnesium chloride was used as the absorbing material in the liquid desiccant and the pressure when measuring the boiling point
20 was 1 bar.

The boiling point for the liquid desiccant increases with increasing concentration as seen in the table below.

Concentration (wt%)	23.7	29.9	33.8	37.5
Boiling temperature (°C)	107.8	113.2	116.2	121

As can be seen in Figure 10 the energy required to increase the concentration increases drastically. Therefore the regeneration step should preferably result in a sufficient concentration, i.e. a concentration sufficient to efficiently absorb water or moisture. A higher concentration would require unnecessary energy and thereby a higher cost.

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