

**REGENERATOR FOR A DEHUMIDIFICATION SYSTEM,
DEHUMIDIFICATION SYSTEM AND METHOD OF REGENERATING
LIQUID DESICCANT**

5 **Cross-reference to Related Applications**

[0001] The present application claims the priority of Singapore patent application no.10201505584P filed on 16 July 2015, the entire contents of which are incorporated herein by reference for all purposes.

10 **Technical Field**

[0002] Embodiments relate generally to regenerators for a dehumidification system, dehumidification systems, and methods of regenerating liquid desiccant.

Background

15 [0003] Traditionally, most dehumidification systems in building air conditioning system are based on conventional mechanical dehumidification. This conventional mechanical dehumidification system utilizes high amount of energy to cool the process air below the dew point temperature and reheat. Hence, liquid desiccant dehumidification systems (LDDS), which are more energy efficient, have recently
20 been considered to replace the conventional mechanical dehumidification system. A conventional LDDS includes a dehumidifier and a regenerator. In the dehumidifier, moisture in process air is removed and transferred to liquid desiccant solution via heat and mass transfer from the process air to the liquid desiccant solution. The mass transfer is due to surface vapor pressure difference between the process air and liquid
25 desiccant solution. In the regenerator, the moisture in the diluted liquid desiccant solution is removed to concentrate the liquid desiccant solution for flowing back into the humidifier. The removal of moisture is via heat and mass transfer from the diluted liquid desiccant solution to an air stream.

[0004] The problem for the conventional LDDS is that dehumidification requires
30 high vapor pressure difference. If low humidity in the process air is required to be generated, the liquid desiccant solution concentration supplied to the dehumidifier has to be high, which requires higher regeneration temperature and hence larger heating energy in the regenerator to a regenerate concentrated liquid desiccant solution. In

addition, the carryover of liquid desiccant solution in the air stream during regeneration is also one of the problems of the conventional LDDS due to the direct contact of the desiccant solution and air streams during heat and mass transfer process in the regenerator.

- 5 **[0005]** Accordingly, example embodiments seek to provide a regenerator for dehumidification system, a dehumidification system, and a method of regenerating liquid desiccant that address at least some of the issues identified above.

Summary

- 10 **[0006]** According to various embodiments, there is provided a regenerator for a dehumidification system. The regenerator may include an enclosed container having a first reservoir and a second reservoir inside the enclosed container, wherein the first reservoir may be configured to receive liquid desiccant from a dehumidifier of the dehumidification system, a heating element configured to heat the liquid desiccant
15 received in the first reservoir, and a condensing element disposed inside the enclosed container and arranged with respect to the second reservoir for condensate to be collected in the second reservoir.

[0007] According to various embodiments, there is provided a dehumidification system including a dehumidifier and a regenerator as described herein.

- 20 **[0008]** According to various embodiments, there is provided a method of regenerating liquid desiccant. The method may include receiving liquid desiccant in a first reservoir of an enclosed container of a regenerator, heating the liquid desiccant received in the first reservoir, and condensing vapor inside the enclosed container into a condensate to be collected in a second reservoir of the enclosed container.

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Brief description of the drawings

- [0009]** In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the
30 following description, various embodiments are described with reference to the following drawings, in which:

FIG. 1 shows an illustration of an example of a conventional liquid desiccant dehumidification system;

FIG. 2A shows a schematic diagram of a regenerator for a dehumidification system according to various embodiments;

FIG. 2B shows a schematic diagram of a regenerator for a dehumidification system according to various embodiments;

5 FIG. 3 shows a schematic diagram of a method of regenerating liquid desiccant according to various embodiments; and

FIG. 4 shows an illustration of a regenerator for a dehumidification system according to various embodiments.

10 **Detailed description**

[0010] Embodiments described below in context of the apparatus are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

15 [0011] It should be understood that the terms “on”, “over”, “top”, “bottom”, “down”, “side”, “back”, “left”, “right”, “front”, “lateral”, “side”, “up”, “down” etc., when used in the following description are used for convenience and to aid understanding of relative positions or directions, and not intended to limit the orientation of any device, or structure or any part of any device or structure. In
20 addition, the singular terms “a”, “an”, and “the” include plural references unless context clearly indicates otherwise. Similarly, the word “or” is intended to include “and” unless the context clearly indicates otherwise.

[0012] FIG. 1 shows an illustration of an example of a conventional liquid desiccant dehumidification system (LDDS) 100. The LDDS 100 may include a
25 dehumidifier 110 and a regenerator 120. Each of the dehumidifier 110 and the regenerator 120 may include a packing bed 114, 124. The packing bed 114, 124 may provide a surface for heat and mass transfer between liquid desiccant solution and air to occur. The moisture of process air may be removed in the dehumidifier 110 whereas the moisture in the diluted liquid desiccant solution may be removed in the
30 regenerator 120.

[0013] In the dehumidifier 110, the pre-cooled concentrated liquid desiccant solution 112 may be sprayed on the top of the packing bed 114 and contact with the process air 116 blowing from the bottom of the packing bed 114. Since the cold liquid

desiccant solution 112 has lower surface vapor pressure than that of the process air 116, heat and mass transfer may take place from the process air 116 to the cold liquid desiccant solution 112. Accordingly, water vapor may be transferred from the process air 116 to the cold liquid desiccant solution 112.

5 **[0014]** In the regenerator 120, the pre-heated liquid desiccant solution 122 may be sprayed on the top of the packing bed 124 and contact with the ambient air 126 blowing from the bottom of the packing bed 124. Since the hot liquid desiccant solution 122 has higher surface vapor pressure than that of the ambient air 126, heat and mass transfer may take place from the hot liquid desiccant solution 122 to the ambient air 126. Accordingly, water vapor may be transferred from the hot liquid desiccant solution 122 to the ambient air 126.

10 **[0015]** As the liquid desiccant temperature difference between the dehumidifier 110 and regenerator 120 is generally about 50°C, an internal heat exchanger 130 may be installed for heat recovery. Further, a cooler 118 and a heater 128 may be required at the respective dehumidifier 110 and regenerator 120 to meet their respective required dehumidifying and regenerating temperatures.

15 **[0016]** The regenerator 120 in a conventional LDDS 100 as described may include packing beds 124 to allow the heat and mass transfer to occur. The mass transfer here refers to the transfer of water vapor from the hot liquid desiccant solution 122 to the ambient air 126 when the liquid desiccant solution 122 and air streams of ambient air 126 contact directly with each other to realize the regeneration process. However, due to the direct contact of the hot liquid desiccant solution 122 and air streams of ambient air 126 during heat and mass transfer process, carryover of hot liquid desiccant solution 122 in the air streams of ambient air 126, which is returned to the environment, may potentially occur, thus polluting the air in the environment.

20 **[0017]** In addition, as the dehumidification requires high vapor pressure difference, if low humidity air is required to be produced by the dehumidifier 110, the concentration of the liquid desiccant solution 112 supplied to the dehumidifier 110 has to be high. Accordingly, in order to regenerate high concentration liquid desiccant solution with the regenerator 120, more water vapor needs to be removed from the liquid desiccant solution 122. The surface vapor pressure of the higher concentration liquid desiccant solution is lower than that of the lower concentration liquid desiccant

solution. Therefore, at certain specified pressure such as atmospheric pressure, higher regeneration temperature and hence larger heating energy are required to provide sufficient surface vapor pressure difference to realize the mass transfer process to obtain higher concentration liquid desiccant solution.

5 **[0018]** Various embodiments seek to provide a regenerator for a dehumidification system, a dehumidification system, and a method of regenerating liquid desiccant that address at least some of the issues identified above. According to various embodiments, the mass transfer process for the regenerator may be via a boiling process of the liquid desiccant solution rather than surface vapor pressure difference.

10 Accordingly, water composition in the diluted desiccant solution may be removed by boiling it into vapor form. The mass transfer process via boiling of the liquid desiccant according to various embodiments may be a faster process than the conventional mass transfer process via surface vapor pressure difference. In addition, the regeneration process according to various embodiments may be conducted under

15 vacuum condition. Hence, no air stream of ambient air may be required in the regeneration process. Thus, there is no risk of carryover of the liquid desiccant solution to the ambient air.

[0019] FIG. 2A shows a schematic diagram of a regenerator 220 for a dehumidification system, such as a liquid desiccant dehumidification system,

20 according to various embodiments. The regenerator 220 may be connectable to a dehumidifier (not shown) of the dehumidification system. The dehumidifier may be configured to remove moisture from process air using concentrated liquid desiccant to absorb the moisture from the process air. The regenerator 220 may include an enclosed container 240. The enclosed container 240 may be configured to receive

25 diluted liquid desiccant from the dehumidifier. The enclosed container 240 may include a first reservoir 256 and a second reservoir 266 inside the enclosed container 240. The first reservoir 256 may be configured to receive the diluted liquid desiccant from the dehumidifier of the dehumidification system. The regenerator 220 may further include a heating element 250 configured to heat the diluted liquid desiccant

30 received in the first reservoir 256 of the enclosed container 240. The regenerator 220 may further include a condensing element 260 disposed inside the enclosed container 240. The condensing element 260 may be arranged with respect to the second reservoir 266 such that condensate from the condensing element 260 may be collected

in the second reservoir 266. In this arrangement, the diluted liquid desiccant in the first reservoir 256 of the enclosed container 240 may be directly heated or boiled such that moisture in the diluted liquid desiccant may turn into vapor and the liquid desiccant may become more concentrated. Further, the vapor in the enclosed container may be condensed into condensate and may be collected in the second reservoir 266 for discharging from the enclosed container 240. Accordingly, moisture in the diluted liquid desiccant may be removed from the diluted liquid desiccant to concentrate the liquid desiccant without requiring the liquid desiccant to have contact with air streams of ambient air, thus reducing or eliminating the risk of carry over of liquid desiccant into the ambient air.

[0020] In other words, the regenerator according to various embodiments may include an airtight tank in fluid communication with the dehumidifier of the dehumidification system such that liquid desiccant used in the dehumidifier to absorb moisture from air may flow into the airtight tank. Accordingly, the airtight tank may provide a sealed volume to contain liquid desiccant that may flow into the tank from the dehumidifier. The airtight tank may include at least two receptacles for receiving fluids. One of the at least two receptacles may be configured to receive the liquid desiccant from the dehumidifier. The regenerator may further include a heater configured to provide heat energy to the liquid desiccant in the first receptacle for heating. The regenerator may also include a condenser disposed inside the airtight tank such that condensate formed on the condenser may be directed into another one of the at least two receptacles.

[0021] FIG. 2B shows a schematic diagram of a regenerator 221 for a dehumidification system according to various embodiments. The regenerator 221 may, similar to the regenerator 220 of FIG. 2A, include an enclosed container 240. The enclosed container 240 may include a first reservoir 256 and a second reservoir 266 inside the enclosed container 240. The first reservoir 256 may be configured to receive liquid desiccant from the dehumidifier of the dehumidification system. The regenerator 221 may, similar to the regenerator 220 of FIG. 2A, further include a heating element 250 configured to heat the liquid desiccant received in the first reservoir 256 of the enclosed container 240. The regenerator 221 may, similar to the regenerator 220 of FIG. 2A, also include a condensing element 260 disposed inside

the enclosed container 240 and arranged with respect to the second reservoir 266 for condensate to be collected in the second reservoir 266.

[0022] According to various embodiments, the second reservoir 266 may be separated from the first reservoir 256 such that they are not in fluid communication.

5 Accordingly, a liquid contained in the second reservoir may be separated from the liquid desiccant contained in the first reservoir 256.

[0023] According to various embodiments, the regenerator 221 may also include a pump 270, such as a vacuum pump, coupled to the enclosed container 240. The pump 270 may be configured to reduce the pressure inside the enclosed container 240. In
10 other words, the regenerator 221 may include a suction device for removing air in the enclosed container 240 so as to create a low pressure or vacuum environment inside the enclosed container 240. Accordingly, the regenerator 221 may be operated such that the pump 270 may generate a low pressure (i.e. lower than atmospheric pressure) or vacuum condition inside the enclosed container 240 which may cause the boiling
15 point of the liquid desiccant contained inside the enclosed container 240 to be lowered. Hence, the heating element 250 may heat up and/or boil the liquid desiccant in the enclosed container 240 at a lower temperature, which may mean that lesser energy may be consumed by the heating element 250 to boil the liquid desiccant. Accordingly, the regenerator 221 according to various embodiments may boil liquid
20 desiccant at a lower temperature under low pressure and/or vacuum condition.

[0024] According to various embodiments, water previously absorbed into the liquid desiccant may be turned into water vapor by the regenerator 221 inside the enclosed container 240 at a lower temperature. Thus, using the regenerator 221 to remove water from the liquid desiccant to regenerate concentrated liquid desiccant
25 may not require large amount of heating energy. Further, since the container 240 is enclosed, the liquid desiccant may not come into direct contact with ambient air during regeneration of the liquid desiccant. Accordingly, the risk of the carryover of liquid desiccant into the environmental air may be reduced or eliminated with the use of the regenerator 221.

30 **[0025]** According to various embodiments, as the regenerator 221 boils the liquid desiccant in the enclosed container 240 under low pressure or vacuum condition, water previously absorbed into the liquid desiccant in the dehumidifier may turn into water vapor inside the enclosed container 240. The water vapor may then come into

contact with the condensing element 260 such that condensed water is formed on the condensing element 260. Since the condensing element 260 and the second reservoir 266 are arranged such that condensate from the condensing element 260 may be collected in the second reservoir 266, the condensed water may then be collected in the second reservoir 266.

[0026] According to various embodiments, the enclosed container 240 may include a primary inlet 242 configured to receive the liquid desiccant and a primary outlet 244 configured to discharge the liquid desiccant. The primary inlet 242 may be in fluid communication with the dehumidifier for flowing the liquid desiccant from the dehumidifier to the enclosed container 240.

[0027] According to various embodiments, the enclosed container 240 may further include an auxiliary inlet 246. The auxiliary inlet 246 may be externally connected to the primary outlet 244. Accordingly, the auxiliary inlet 246 may be in fluid communication with the primary outlet 244 via a fluid path outside the enclosed container 240. In this manner, liquid desiccant flowing out of the enclosed container 240 may be re-circulated back or returned to the enclosed container 240 if the concentration of the liquid desiccant from the primary outlet 244 is below a desired level of concentration.

[0028] According to various embodiments, the regenerator 221 may further include a liquid concentration measuring device 284 connected to the primary outlet 244 along the fluid path outside the enclosed container 240. The liquid concentration measuring device 284 may be configured to measure the concentration level of the liquid desiccant flowing out of the primary outlet 244 of the enclosed container 240. If the concentration level of the liquid desiccant is below the desired level of concentration, the liquid desiccant may be redirected back to the enclosed container 240 via the auxiliary inlet 246.

[0029] According to various embodiments, the regenerator 221 may further include a storage tank 280 in fluid communication with the enclosed container 240. Accordingly, if the concentration level of the liquid desiccant flowing out of the enclosed container 240 via the primary outlet 244 has reached the desired concentration level, the liquid desiccant may be directed to flow to the storage tank 280.

[0030] According to various embodiments, the regenerator 221 may further include a pressure sensing device 272 disposed in the enclosed container. The pressure sensing device 272 may provide feedback on the pressure inside the enclosed container 240 such that the pump 270 may be operated accordingly to maintain a
 5 desired level of pressure in the enclosed container 240. According to various embodiments, the pressure sensing device 272 may be coupled to the pump 270 such that a feedback loop is provided for automated operation of the pump 270 to maintain the level of pressure in the enclosed container 240.

[0031] According to various embodiments, the condensing element 260 may be
 10 connected to a cooling source which may include any one of but is not limited to chilled water from a chiller, cooling sea water, cooling water from cooling tower, chilled plant condensed water, cooling water or an evaporator in a heat pump cycle. According to various embodiments, the heating element 250 may be connected to a heating source which may include any one of but not limited to a condenser in a heat
 15 pump cycle, solar energy or any other low grade renewable energy. In this arrangement, the cooling source may be connected to the condensing element 260 to provide the cooling effect and the heating source may be connected to the heating element 250 to provide the heat energy for heating. Accordingly, by utilizing the low grade or renewable energy as the cooling and heating source, the regenerator 220 may
 20 operate under high energy efficiency.

[0032] According to various embodiments, there may be provided a dehumidification system including a dehumidifier and a regenerator as described herein, wherein the regenerator is connected to the dehumidifier.

[0033] FIG. 3 shows a schematic diagram of a method 300 of regenerating liquid
 25 desiccant. At 302, liquid desiccant may be received in a first reservoir of an enclosed container of a regenerator. The liquid desiccant may be from a dehumidifier of a dehumidification system and may have absorbed moisture in the dehumidifier such that the liquid desiccant is diluted. At 304, the liquid desiccant received in the first reservoir of the enclosed container may be heated. At 306, vapor inside the enclosed
 30 container may be condensed into a condensate to be collected in a second reservoir of the enclosed container. Accordingly, the liquid desiccant in the first reservoir may be directly heated or boiled such that moisture in the liquid desiccant may turn into vapor. Subsequently, the vapor may be condensed into condensate which may then be

removed from the enclosed container. In this manner, moisture in the liquid desiccant may be removed from the liquid desiccant to increase the concentration of liquid desiccant within an enclosed environment without requiring the liquid desiccant to interact with air streams of ambient air. Accordingly, the risk of carry over of liquid desiccant in the ambient air may be reduced or eliminated.

[0034] According to various embodiments, the heating of the liquid desiccant may be performed under low pressure or vacuum conditions. Accordingly, the liquid desiccant may be heated and/or boiled such that water previously absorbed into the liquid desiccant may be turned into water vapor by the heating inside the enclosed container at a lower temperature. In this manner, water may be removed from the liquid desiccant such that the liquid desiccant may be regenerated into concentrated liquid desiccant without requiring large amount of heating energy.

[0035] According to various embodiments, the method may further include determining the concentration of the liquid desiccant.

[0036] According to various embodiments, the method may further include pumping the liquid desiccant from the enclosed container into a storage tank. Accordingly, the liquid desiccant may be pumped into the storage tank when the liquid desiccant has reached a desired concentration level.

[0037] According to various embodiments, the method may further include pumping the liquid desiccant out of the enclosed container and reintroduce into the enclosed container. Accordingly, the liquid desiccant may be re-circulated back to the enclosed container when the liquid desiccant is below the desired level of concentration.

[0038] According to various embodiments, water that is removed from the liquid desiccant from heating or boiling may be condensed to form condensed water.

[0039] According to various embodiments, the method may further include discharging the condensate from the enclosed container. Accordingly, the condensed water may be discharge from the enclosed container.

[0040] According to various embodiments, the heating and the condensing may be via a low grade or renewable energy sources arrangement. Accordingly, this may provide a high energy efficiency arrangement for the heating and the condensing.

[0041] FIG. 4 shows an illustration of a regenerator 420 for a liquid desiccant dehumidification system (LDDS) according to various embodiments. As shown, the

regenerator 420 may include an enclosed container 440. The enclosed container 440 may be a solution tank or vessel. The enclosed container 440 may be in the form of cylindrical or cuboid or any other suitable shape. The enclosed container 440 may be configured to receive diluted liquid desiccant solution from a dehumidifier (not shown). The diluted liquid desiccant solution may have absorbed moisture or water vapor from process air in the dehumidifier of the LDDS. The enclosed container 440 may include a primary inlet 442 in fluid communication with the outlet of the dehumidifier via a fluid inflow line 441 such that diluted liquid desiccant solution may flow from the dehumidifier into the enclosed container 440 of the regenerator 420. A regulator or valve 492 may be located along the fluid inflow line 441 to regulate the flow of the diluted liquid desiccant solution into the enclosed container 440. The enclosed container 440 may further include a first reservoir 456 to contain liquid desiccant solution 422 received inside the enclosed container 440.

[0042] As shown in FIG. 4, the regenerator 420 may include a heating element (or a generator) 450 and a condensing element (or a condenser) 460. The heating element 450 and the condensing element 460 may be disposed inside the enclosed container 440. The heating element 450 may be connected to a heating source 452. The condensing element 460 may be connected to a cooling source 462. The regenerator 420 may further include a vacuum pump 470 coupled to the enclosed container 440 such that a low pressure and/or vacuum condition may be created inside the enclosed container 440. Accordingly, the heating element 450 and the condensing element 460 may operate in the low pressure and/or vacuum condition.

[0043] According to various embodiments, the heating element 450 may generate heat to boil the liquid desiccant solution 422 contained inside the enclosed container 440. Both the water composition and liquid desiccant composition in the liquid desiccant solution 422 have different boiling temperatures. When the liquid desiccant solution 422 is heated up by the heating element 450 at certain pressure, only the water composition in the liquid desiccant solution 422 may be boiled instead of both the water composition and the liquid desiccant composition as the boiling temperature of the water composition is lower than that of the liquid desiccant composition. Therefore, the water composition in the liquid desiccant solution 422 may boil at a lower temperature in low pressure vacuum condition and hence the liquid desiccant

solution 422 may become more concentrated as the water composition inside the liquid desiccant solution 422 may be reduced due to boiling.

[0044] The low pressure and/or vacuum condition created in the regenerator 420 according to various embodiments provides an advantage as the low pressure and/or vacuum condition may lower the boiling temperature of the liquid desiccant solution 422 and hence the water composition in the liquid desiccant solution 422 may be boiled at a lower temperature. The vacuum pump 470 may realize the low pressure and/or vacuum condition in the regenerator 420. Further, a pressure gauge 472 may also be placed in the enclosed container 432 to provide feedback for maintaining the low pressure vacuum condition inside the enclosed container 432. The pressure gauge 472 may be coupled to the vacuum pump 370.

[0045] According to various embodiments, the liquid desiccant solution 422 may be pumped out from the enclosed container 440 via a primary outlet 444 and inserted again from the top of the enclosed container 440 via an auxiliary inlet 446 for the regeneration process. Accordingly, the primary outlet 444 may be in fluid communication with the auxiliary inlet 446 via a fluid return line 445 outside the enclosed container 440. According to various embodiments, the auxiliary inlet 446 may be configured such that the liquid desiccant solution 422 being returned to the enclosed container 440 may be sprayed into the enclosed container 440. For example, a nozzle may be disposed inside the enclosed container 440 and may be in fluid communication with the auxiliary inlet 446 such that the liquid desiccant solution 422 returning through the auxiliary inlet 446 may be sprayed into the enclosed container 440. This process may be repeated until the required concentration level of liquid desiccant solution is reached. After which, the concentrated liquid desiccant solution may be pumped to a storage tank 480 before sending to the dehumidifier for dehumidification process. Accordingly, the storage tank 480 may also be in fluid communication with the primary outlet 444 via a fluid outflow line 481. According to various embodiments, a three-way valve 482 may be connected to the primary outlet 444 such that the primary outlet 444 may be connected to the fluid return line 445 for directing fluid to the auxiliary inlet 446 and the fluid outflow line 481 for directing fluid to the storage tank 480. A pump 494 may be connected to the primary outlet 444 for pumping the fluid through either the fluid return line 445 or the fluid outflow line 481. A liquid concentration measuring device 484 may be located along a flow line

between the primary outlet 444 and the three-way valve 482 and may be connected to the primary outlet 444 such that the concentration of the liquid desiccant solution may be determined. Thus, the three-way valve 482 may be operated to direct flow to the fluid return line 445 when the concentration is below the desired level and direct flow
 5 to the fluid outflow line 481 when the concentration has reached the desired level.

[0046] According to various embodiments, due to the different boiling temperature of the water composition and the liquid desiccant composition in the liquid desiccant solution 422, vapor generated from boiling of the liquid desiccant solution 422 which may include only water composition, may flow to the condensing
 10 element 460. The vapor may release the latent heat of condensation and water 428 may be formed. The enclosed container 440 may include a second reservoir 466 for collecting the water 428 formed. Accordingly, the condensing element 460 and the second reservoir 466 may be disposed and arranged with respect to each other such that water condensed by the condensing element 460 may be collected in the second
 15 reservoir 466. The enclosed container 440 may further include an auxiliary outlet 448 connected to the second reservoir 466 such that the accumulated water 428 may be drained from the second reservoir 466. Accordingly, water 428 accumulated in the second reservoir 466 may then be pumped out from the enclosed container 440. A regulator or valve 496 may be connected to the auxiliary outlet 448 to control the rate
 20 of flow of water out of the enclosed container 440. A pump 498 may also be connected to the auxiliary outlet 448 to pump the water out of the enclosed container 440.

[0047] According to various embodiments, the first reservoir 456 and the second reservoir 466 may be of any suitable configuration such that the first reservoir 456
 25 may contain liquid desiccant solution received from the dehumidifier and the second reservoir 466 may separately contain water formed from condensation. As shown in FIG. 4, the first reservoir 456 may be a base of the enclosed container 440 and the second reservoir 466 may be a horizontal plate with raised edges attached to a side wall of the enclosed container 440 to form a receptacle for collecting condensed
 30 water. According to other embodiments, a base of the enclosed container may be separated by a partition wall (not shown) such that the first reservoir may be on one side of the partition wall and the second reservoir may be on the other side of the partition wall.

[0048] As shown in FIG. 4, the enclosed container 440 may further include a shielding panel 468 disposed at the top of the enclosed container 440. The shielding panel 468 may extend downward from the top of the enclosed container 440. Further, the shielding panel 468 may be positioned such that it may be directly facing the auxiliary inlet 446 and may be between the auxiliary inlet 446 and the second reservoir 466. Accordingly, the shielding panel 468 may be configured to ensure that the liquid desiccant solution 422 being returned through the auxiliary inlet 446 may not be sprayed into the second reservoir 466. Accordingly, the shielding panel 468 may function as a shield for blocking the liquid desiccant solution 422 re-entering the enclosed container 440 through the auxiliary inlet 446 from being sprayed into the second reservoir 466.

[0049] According to various embodiments, the heating source 452 may supply the heat to the heating element 450 to heat up and/or boil the liquid desiccant solution 422 to produce vapor in order to concentrate the liquid desiccant solution 422. The heating source 452 may include but is not limited to low grade energy, solar energy, condenser in heat pump cycle and etc.

[0050] According to various embodiments, the cooling source 462 may absorb the latent heat of condensation released from the vapor formed in the condensing element 460. The cooling source 462 may include but is not limited to cooling water, evaporator in heat pump cycle and etc.

[0051] According to various embodiments, the heating element 450 and the cooling element 460 may be connected in a heat pump cycle (not shown). Accordingly, the heating element 450 and the cooling element 460 may be components of a heat pump cycle. In this arrangement, the evaporator of the heat pump may be the cooling source 462 for the condensing element 460 and the condenser of the heat pump may be the heating source 452 for the heating element 450. With the regeneration process driven by the heat pump in which both the evaporator and the condenser of the heat pump may be utilized as the cooling and heating source of the regenerator, the regenerator according to various embodiments may have high energy efficiency.

[0052] Various embodiments have provided an absorption-based liquid desiccant regenerator (ALDR) for a liquid desiccant dehumidification system (LDDS) that may address the issues with conventional LDDS as discussed earlier. The regenerator of

the LDDS according to various embodiments may include heating element and condensing element. In addition, the vacuum condition may also be applied in the regeneration process according to various embodiments.

[0053] Advantageously, various embodiments performing regeneration in vacuum condition may reduce the boiling temperature of the diluted desiccant solution. Therefore, low grade heating energy, as a non-limiting example, may be used in the absorption-based regenerator for higher solution concentration to increase the energy efficiency.

[0054] Further, low grade energy or renewable energy may also be used in various embodiments for energy savings by shifting away from the electrical energy. According to various embodiments, any heating and cooling sources may be used. For instance, the heating source connected to the heating element may include but is not limited to condenser in heat pump cycle, solar energy and any other low grade renewable energy. The cooling source for the condensing element according to various embodiments may include but is not limited to chilled water from a chiller, cooling sea water, cooling water from cooling tower, chiller plant condensed water, cooling water and evaporator in heat pump cycle.

[0055] Furthermore, no air stream may be needed in various embodiments as the regeneration process here is through boiling process and hence it is a faster process.

Besides, there is no carryover problem and no fan power is required here.

[0056] In addition, in various embodiments, batch operation may be the continuous effect operation of the liquid desiccant solution where the liquid desiccant solution is circulated continuously in the liquid desiccant solution loop until the required liquid desiccant solution concentration is reached. This operation may avoid unnecessary cooling and heating of the liquid desiccant solution as in the conventional regenerator in LDDS system. Therefore, the energy consumption according to various embodiments is expected to be lower than that of in the conventional LDDS.

[0057] Moreover, to regenerate higher concentration of the liquid desiccant solution, typically, more heating energy is needed for the conventional LDDS. In contrast, according to various embodiments, the boiling point of the liquid desiccant solution may be maintained by providing lower pressure vacuum condition in the regeneration tank using the vacuum pump without increasing the heating energy.

Accordingly, various embodiments may be more energy efficiency than the conventional LDDS.

[0058] Additionally, various embodiments may be applicable for all types of liquid desiccants.

5 **[0059]** While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes, modification, variation in form and detail may be made therein without departing from the scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes
10 which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

1. A regenerator for a dehumidification system, comprising:
an enclosed container having a first reservoir and a second reservoir inside the
5 enclosed container, wherein the first reservoir is configured to receive liquid desiccant
from a dehumidifier of the dehumidification system;
a heating element configured to heat the liquid desiccant received in the first
reservoir; and
a condensing element disposed inside the enclosed container and arranged
10 with respect to the second reservoir for condensate to be collected in the second
reservoir .
2. The regenerator as claimed in claim 1, further comprising a pump coupled to
the enclosed container, wherein the pump is configured to reduce the pressure in the
15 enclosed container.
3. The regenerator as claimed in claim 1 or 2, wherein the enclosed container
comprises a primary inlet configured to receive the liquid desiccant and a primary
outlet configured to discharge the liquid desiccant.
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4. The regenerator as claimed in claim 3, wherein the enclosed container further
comprises an auxiliary inlet, and wherein the auxiliary inlet is externally connected to
the primary outlet.
- 25 5. The regenerator as claimed in claim 3 or 4, further comprising a liquid
concentration measuring device connected to the primary outlet.
6. The regenerator as claimed in any one of claims 1 to 5, further comprising a
storage tank in fluid communication with the enclosed container.
- 30 7. The regenerator as claimed in any one of claims 1 to 6, further comprising a
pressure sensing device disposed in the enclosed container.

8. The regenerator as claimed in any one of claims 1 to 7, wherein the condensing element is connected to a cooling source comprising any one of chilled water from a chiller, cooling sea water, cooling water from cooling tower, chilled plant condensed water, cooling water or an evaporator in a heat pump cycle.

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9. The regenerator as claimed in any one of claims 1 to 8, wherein the heating element is connected to a heating source comprising any one of a condenser in a heat pump cycle, solar energy or any other low grade renewable energy.

10 10. A dehumidification system comprising:
a dehumidifier; and
a regenerator according to any one of claims 1 to 9 connected to the dehumidifier.

15 11. A method of regenerating liquid desiccant, the method comprising:
receiving liquid desiccant in a first reservoir of an enclosed container of a regenerator;
heating the liquid desiccant received in the first reservoir; and
condensing vapor inside the enclosed container into a condensate to be
20 collected in a second reservoir of the enclosed container.

12. The method of claim 11, wherein heating is under low pressure or vacuum conditions.

25 13. The method of claim 11 or 12, further comprising determining the concentration of the liquid desiccant.

14. The method of any one of claims 11 to 13, further comprising pumping the liquid desiccant from the enclosed container into a storage tank.

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15. The method of any one of claims 11 to 13, further comprising pumping the liquid desiccant out of the enclosed container and reintroduce into the enclosed container.

16. The method of any one of claims 11 to 15, further comprising discharging the condensate from the enclosed container.
- 5 17. The method of any one of claims 11 to 16, wherein heating and condensing is via low grade or renewable energy source.