

GAS HUMIDITY REGULATING METHOD AND REGULATOR

[Technical Field]

[0001]

5 The present invention relates to a gas humidity
regulating method and a regulator that control water content
in the air, that is, humidity in, for example, a hospital, a
nursing home, an office, a sports facility, a food factory,
and a pharmaceutical factory.

10

[Background Art]

[0002]

Such a regulator is known as a liquid-desiccant air
conditioner where a liquid desiccant (drying agent) is used.
15 The liquid-desiccant air conditioner is combined with a heat
pump so as to separate latent heat and sensible heat, and can
construct an energy-saving air conditioning system.

[0003]

20 For example, a wet desiccant apparatus is disclosed in
Patent Literature 1. The wet desiccant apparatus includes a
dehumidifying unit that allows water content absorption into
a liquid desiccant (absorbent); a recycling unit that
releases water content in the liquid desiccant; a
25 dehumidifying unit pump that transports an absorbent from the
dehumidifying unit to the recycling unit; a recycling unit
pump that transports the absorbent in the reverse direction;
and a pump controller that drives the pumps under
predetermined conditions.

[0004]

Specifically, the dehumidifying unit includes a case and a structure provided with a fin or the like in the case. An inlet port for feeding air subjected to treatment is provided
5 in the lower part of the case while an outlet port for discharging dehumidified air subjected to treatment is provided in the upper part of the case. While the liquid desiccant is poured to the structure, air subjected to treatment from the inlet port is brought into contact with
10 the liquid desiccant to absorb water content from the air subjected to treatment into the liquid desiccant. The dehumidified air subjected to treatment is discharged from the outlet port.

15 [0005]

The recycling unit has the same configuration as the dehumidifying unit. While the liquid desiccant having absorbed water content from the dehumidifying unit is poured to the structure, air to be recycled from the inlet port is
20 brought into contact with the liquid desiccant to remove water content from the liquid desiccant into the air, and then the moisturized air is discharged from the outlet port.

[Citation List]

[Patent Literature]

[0006]

- 5 [Patent Literature 1] Japanese Patent Laid-Open No. 2010-54136

[Summary of Invention]

[Technical Problems]

10

[0007]

In the wet desiccant apparatus having a related-art configuration according to Patent Literature 1, the liquid desiccant in the dehumidifying unit is raised in temperature
15 by heat generated when water content in air subjected to treatment is absorbed into the liquid desiccant. Thus, the saturation vapor pressure of the liquid desiccant increases in the case so as to suppress water content absorption into the liquid desiccant. This may reduce humidity-control
20 efficiency.

[0008]

In addition, when the liquid desiccant having absorbed water content is poured to the structure, the temperature of
25 the liquid desiccant decreases in the recycling unit so as to suppress movement of water content from the liquid desiccant into air to be recycled. This may reduce humidity-control efficiency.

[0009]

An object of the present invention is to provide a gas humidity regulating method and a regulator that can regulate a temperature during humidity control and improve humidity-
5 control efficiency.

[Solution to Problems]

[0010]

10 In order to attain the object, in a gas humidity regulating method of the present invention, a gas-liquid contact part having a heat exchanging pipe is provided in a gas-liquid contact case having an inlet port for feeding gas subjected to treatment and an outlet port for discharging
15 treated gas, a first medium serving as a liquid desiccant is caused to flow onto the gas-liquid contact part, and a second medium for regulating a temperature is passed through the heat exchanging pipe. In this state, gas subjected to treatment is fed from the inlet port into the gas-liquid
20 contact case, a gas-liquid contact is made by the first medium on the gas-liquid contact part so as to absorb water content into the first medium from the gas subjected to treatment, and then the treated gas is discharged from the outlet port.

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[0011]

Thus, gas subjected to treatment and the first medium make a gas-liquid contact on the gas-liquid contact part and water content in gas subjected to treatment is absorbed into

the first medium serving as a liquid desiccant. At this point, the second medium is passed through a heat exchanging pipe constituting the gas-liquid contact part so as to regulate the temperature of the first medium on the gas-
5 liquid contact part. This can accelerate dehumidification or humidification so as to increase humidity-control efficiency.

[Advantageous Effect of Invention]

10 [0012]

According to a gas humidity regulating method according to the present invention, a temperature can be regulated during humidity control, thereby improving humidity-control efficiency.

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[Brief Description of the Drawings]

[0013]

[Figure 1] Figure 1 is an explanatory drawing schematically showing an air humidity regulator including a dehumidifier and a humidifier according to an embodiment.
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[Figure 2] Figure 2(a) is a front view showing a gas-liquid contact structure on a gas-liquid contact part for the dehumidifier or the humidifier, and Figure 2(b) is an
25 explanatory drawing schematically showing the gas-liquid contact structure.

[Figure 3] Figure 3(a) is a perspective view showing the gas-liquid contact structure in the dehumidifier or the humidifier, and Figure 3(b) is a perspective view showing the

gas-liquid contact structure on a gas-liquid contact part of the related art.

[Figure 4] Figure 4 is a graph showing the relationship between a flow rate and an absolute humidity of a first medium in examples or a comparative example.

The x-axis in Figure 4 shows the flow rate of a first medium (in " $\text{kg}/\text{m}^2 \cdot \text{s}$ "). The y-axis in Figure 4 shows the absolute humidity of a first medium (in " g/kg ").

The meaning of the dots in Figure 4 represent the results obtained for the solution of each example as follows:

Example 1: $\odot$; Example 2: $\triangle$; Example 3: $\diamond$;
 Example 4: $\square$; Example 5: $\times$; Example 6: $*$;
 Example 7: $+$; Comparative Example 1: $\circ$.

15

[Figure 5] Figure 5 is a graph showing the relationship between a viscosity and a saturation vapor pressure of the first medium in the examples and the comparative example.

20 The x-axis in Figure 5 shows the viscosity of a first medium (in " $\text{mPa} \cdot \text{s}$ "). The y-axis in Figure 5 shows the saturation vapor pressure of a first medium (in " kPa ").

The meaning of the dots in Figure 5 represent the results obtained for the solution of each example as follows:

25

Example 1: $\odot$; Example 2: Δ ; Example 3: $\diamond$;
 Example 4: $\square$; Example 5: $\times$; Example 6: $*$;
 Example 7: $+$; Comparative Example 1: $\circ$.

- 5 [Figure 6] Figure 6 is a graph showing the relationship between a flow rate and an absolute humidity of the first medium in the examples or the comparative example.

The x-axis in Figure 6 shows the flow rate of a first medium
 10 (in " $\text{kg}/\text{m}^2 \cdot \text{s}$ "). The y-axis in Figure 6 shows the absolute humidity of a first medium (in " g/kg ").

The meaning of the dots in Figure 6 represent the results obtained for the solution of each example as follows:

Examples 1 to 4 (mean value): $\odot$; Comparative Example 1: $\circ$.
 15

[Description of Embodiment]

[0014]

An embodiment of the present invention will be
 20 specifically described below in accordance with the accompanying drawings.

[0015]

Figure 1 is a schematic diagram showing a gas humidity
 25 regulator 10 according to the present embodiment. The regulator 10 includes a dehumidifier 11 and a humidifier 12 that are connected to each other. The dehumidifier 11 and the humidifier 12 have identical basic configurations. The dehumidifier 11 will be first discussed below.

[0016]

As shown in Figure 1, an inlet port 14 for feeding air as gas subjected to treatment is formed on a side wall 13a of a gas-liquid contact case 13 that constitutes the gas humidity regulator 10, and an outlet port 15 for discharging treated air is formed on an upper wall 13b of the gas-liquid contact case 13.

[0017]

As shown in Figures 2(a) and 2(b), the gas-liquid contact case 13 contains a meandering heat exchanging pipe 17 with a fin 16 provided on the surface of the heat exchanging pipe 17. The heat exchanging pipe 17 constitutes a dehumidifying unit serving as a gas-liquid contact part 18. The heat exchanging pipe 17 and the fin 16 are made of metals such as aluminum, stainless steel or alloys and can improve a heat exchanging function.

[0018]

As shown in Figure 3(a), for example, the heat exchanging pipe 17 includes meandering pipes 19 that are horizontally arranged in parallel in five rows, the pipe 19 vertically extending so as to meander at regular intervals. As shown in Figure 3(b), the gas-liquid contact part 18 for gas-liquid contact of the related art has paper contact members 51 that are disposed at regular intervals. The gas-liquid contact part 18 is configured such that an absorbent flows along the surfaces of the contact members 51.

[0019]

As shown in Figure 1, a sprinkling pipe 21 having a plurality of discharge ports 20 at the bottom of the sprinkling pipe 21 is disposed above the heat exchanging pipe 17. A receiving pan 23 for receiving a first medium 22 is disposed below the heat exchanging pipe 17. A mixed solution of water and a solution mainly composed of an ionic liquid serving as the first medium 22 is sprayed from the discharge ports 20 of the sprinkling pipe 21 to the fin 16 and the heat exchanging pipe 17, so that the first medium 22 is deposited and stays on the surface of the heat exchanging pipe and an excess of the first medium 22 is collected in the receiving pan 23.

15 [0020]

Moreover, a flowmeter 32 and a thermometer 33 are connected to the inlet port of the heat exchanging pipe 17 while the thermometer 33 is connected to the outlet port of the heat exchanging pipe 17. This configuration allows measurements of the flow rate and temperature of a second medium 24.

[0021]

The first medium 22 sprayed from the sprinkling pipe 21 preferably has a flow rate of 0.5 to 10 kg/m²·s. If the flow rate of the first medium 22 is lower than 0.5 kg/m²·s, only a small amount of water content is absorbed into the first medium 22 from the air, disadvantageously leading to a poor dehumidifying function. If the flow rate of the first medium

22 is higher than $10 \text{ kg/m}^2\cdot\text{s}$, the flow rate is so excessive that water content in the air is hard to absorb any more. Thus, an improvement of the dehumidifying function is not expected and the first medium 22 may be wasted.

5

[0022]

In the dehumidifier 11, air fed from the inlet port 14 comes into contact with the fin 16 and the first medium 22 on the surface of the heat exchanging pipe 17, the air comes
10 into contact with the flowing first medium 22, water content in the air is absorbed by an ionic liquid in the first medium 22, and then the dehumidified air is discharged from the outlet port 15.

15 [0023]

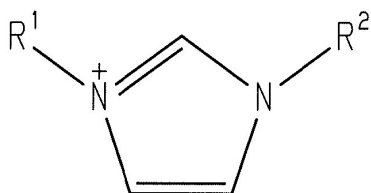
A solution mainly composed of an ionic liquid is preferably used as a liquid desiccant. A preferably used ionic liquid with high water absorbency and noncorrosive properties to metals is expressed by a chemical formula C^+A^-
20 where C^+ is 1,3-dialkylimidazolium cation and A^- is acid anion. As an alkyl group, an alkyl group containing 1 to 4 carbon atoms is preferable and a methyl group or an ethyl group is more preferable. Preferable acid anion is sulfonate anion, phosphate anion, or carboxylate anion.

25

[0024]

The 1,3-dialkylimidazolium cation is expressed by the following chemical formula (1):

[Formula 1]



where R^1 and R^2 are alkyl groups containing 1 to 4 carbon atoms.

5

[0025]

Specifically, the ionic liquid is selected from 1,3-dimethylimidazolium acetate (anion is CH_3COO^-), 1,3-dimethylimidazolium methylsulfonate (anion is SO_3H^-),
 10 1-ethyl-3-methyl imidazolium diethylphosphate [anion is $(\text{C}_2\text{H}_5)_2\text{PO}_3^-$], 1,3-dimethylimidazolium propionate (anion is $\text{C}_2\text{H}_5\text{COO}^-$). Most preferably, the ionic liquid is 1-ethyl-3-methyl imidazolium diethylphosphate [anion is $(\text{C}_2\text{H}_5)_2\text{PO}_3^-$].
 When the ionic liquid is selected from
 15 1,3-dimethylimidazolium acetate (anion is CH_3COO^-), 1,3-dimethylimidazolium methylsulfonate (anion is SO_3H^-), 1-ethyl-3-methyl imidazolium diethylphosphate [anion is $(\text{C}_2\text{H}_5)_2\text{PO}_3^-$], 1,3-dimethylimidazolium propionate (anion is $\text{C}_2\text{H}_5\text{COO}^-$), it is preferred to carry out humidification at
 20 40 °C to 90 °C, in particular 50 °C to 80 °C, even more preferably 45 °C to 70 °C, even more preferably 50 °C to 60 °C, and most preferably 55 °C.

[0026]

25 The solution mainly composed of ionic liquid contains media such as water and other components. The amount of ionic

liquid contained in the solution is preferably 60 to 99, preferably 60 to 90, or alternatively 70 to 99 mass%. If not stated differently, "mass %" give the percentage of a certain substance (for example, ionic liquid) with respect to the weight of the complete solution.

[0027]

The ionic liquid satisfactorily functions as a liquid desiccant with proper viscosity and thus the first medium 22 is used as a mixed solution of water and a solution mainly composed of the ionic liquid. The ionic liquid in the first medium 22 preferably has a concentration of 60 to 90, preferably 70 to 80, mass%. If the concentration of the ionic liquid falls below 60 mass%, the concentration of the ionic liquid is extremely low in the mixed solution, so that the water absorbency of the ionic liquid disadvantageously decreases. If the concentration of the ionic liquid exceeds 90 mass%, the viscosity of the mixed solution excessively increases, resulting in poor contact between the air and the ionic liquid so as to deteriorate water absorbency.

[0028]

When the concentration of the ionic liquid is 80 mass%, the first medium 22 preferably has a low saturation vapor pressure at 35°C. For example, a saturation vapor pressure of 1.9 kPa or less is preferable. However, ionic liquid having a low saturation vapor pressure is likely to become unstable and thus it is desirable to selectively use kinds of ionic liquid. If the saturation vapor pressure of the first medium

22 exceeds 1.9 kPa, water absorbency disadvantageously decreases due to vapor-liquid equilibrium.

[0029]

5 The first medium 22 preferably has a viscosity of 13 to 21 mPa·s. If the viscosity of the first medium 22 is lower than 13 mPa·s, the first medium 22 has a high saturation vapor pressure, disadvantageously reducing water absorbency. If the viscosity of the first medium 22 is higher than 21
10 mPa·s, the first medium 22 decreases in flowability and deteriorates gas-liquid contact between the air and the first medium 22, reducing water absorbency.

[0030]

15 In the heat exchanging pipe 17, the second medium 24 flows and exchanges heat with the surface of the heat exchanging pipe 17 and the first medium 22 on the surface of the fin 16 (mainly by cooling). This adjusts the temperature of the first medium 22 so as to regulate water absorbency.
20 The second medium 24 may be water, hydrofluorocarbon (HFC), or hydrofluoroolefin (HFO). Water is the most preferable in view of heat exchanging capability and ease of handling.

[0031]

25 The temperature of the second medium 24 is preferably equal to or lower than that of the first medium 22. At this point, the water absorbency of the first medium 22 is increased on the gas-liquid contact part 18, thereby improving dehumidification efficiency.

[0032]

A container 25 is placed below the receiving pan 23. The first medium 22 collected in the receiving pan 23 is stored and accumulated in the container 25. One end of a first
5 connecting pipe 26 is connected to the bottom of the container 25.

[0033]

The humidifier 12 will be discussed below. The basic
10 configuration of the humidifier 12 is identical to that of the dehumidifier 11. Thus, the same parts are indicated by the same reference symbols and the explanation thereof is omitted.

15 [0034]

The first connecting pipe 26 connected to the container 25 of the dehumidifier 11 is connected to a sprinkling pipe 21 of the humidifier 12 via a valve 31 through a heat exchanger 27 provided between the dehumidifier 11 and the
20 humidifier 12. A heat exchanging pipe 17 in the humidifier 12 constitutes a humidifying unit serving as a gas-liquid contact part 18. One end of a second connecting pipe 28 is connected to the bottom of a container 25 in the humidifier 12. The second connecting pipe 28 is connected to the
25 sprinkling pipe 21 of the dehumidifier 11 via the valve 31 through the heat exchanger 27. Moreover, the flowmeter 32 and the thermometer 33 are connected to the first connecting pipe 26 and the second connecting pipe 28 so as to measure a flow rate and a temperature of the first medium 22.

[0035]

The temperature of the second medium 24 is preferably equal to or higher than that of the first medium 22. At this point, water release from the first medium 22 is increased on
5 the gas-liquid contact part 18, thereby improving humidification efficiency.

[0036]

In the humidifier 12, air fed from an inlet port 14
10 comes into contact with the first medium 22 on the surface of the heat exchanging pipe 17 and droplets of the flowing first medium 22, water content in the first medium 22 is released into the air, and then the humidified air is discharged from an outlet port 15.

15

[0037]

The effects of the air humidity regulator 10 and the regulating method according to the present embodiment will be described below.

20

[0038]

As shown in Figure 1, in dehumidification of humid air, the first medium 22 containing an ionic liquid is sprayed from the discharge ports 20 of the sprinkling pipe 21 in the
25 dehumidifier 11 to the fin 16 and the heat exchanging pipe 17 that serve as the gas-liquid contact part 18. In this state, humid air is blown to the gas-liquid contact part 18 from the inlet port 14 of the gas-liquid contact case 13.

[0039]

At this point, the air comes into contact with droplets of the first medium 22 and the first medium 22 deposited on the surface of the heat exchanging pipe 17, causing gas-
5 liquid contact. Since the first medium 22 contains the ionic liquid having high water absorbency, water content in the air is absorbed into the ionic liquid on the gas-liquid contact part 18 so as to reduce a water content in the air, achieving dehumidification.

10

[0040]

Additionally, the second medium 24 passes through the heat exchanging pipe 17 on the gas-liquid contact part 18. This exchanges heat between the second medium 24 and the
15 first medium 22 on the surface of the heat exchanging pipe 17. Specifically, the first medium 22 on the surface of the heat exchanging pipe 17 is cooled and water content absorption from the air into the ionic liquid is accelerated. This can also suppress a temperature increase caused by heat
20 generated in water content absorption into the ionic liquid. Thus, the air can be quickly dehumidified with a high rate of dehumidification.

[0041]

25 The effects of the specifically discussed embodiment will be described below.

[0042]

(1) In the air humidity regulating method of the present embodiment, the first medium 22 is caused to flow onto the heat exchanging pipe 17 of the gas-liquid contact part 18 in the dehumidifier 11; meanwhile, the second medium 24 is passed through the heat exchanging pipe 17. In this state, air is fed into the gas-liquid contact case 13 from the inlet port 14 and gas-liquid contact is made by the first medium 22 on the gas-liquid contact part 18 so as to absorb water content from the air into the first medium 22. After that, the treated air is discharged from the outlet port 15.

[0043]

Thus, the air and the first medium 22 make a gas-liquid contact on the gas-liquid contact part 18 and water content in the air is absorbed into the first medium 22 serving as a liquid desiccant. In this case, the second medium 24 passes through the heat exchanging pipe 17 constituting the gas-liquid contact part 18 and thus the temperature of the first medium 22 can be regulated on the gas-liquid contact part 18, thereby accelerating dehumidification.

[0044]

In the humidifier 12, the first medium 22 of the dehumidifier 11 is fed into the sprinkling pipe 21 from the first connecting pipe 26 and then is sprayed to the gas-liquid contact part 18. At this point, air fed into the gas-liquid contact case 13 makes a gas-liquid contact with the first medium 22 and then water content in the first medium 22

is released into the air. Also in this case, the second medium 24 is passed through the heat exchanging pipe 17 and thus the temperature of the first medium 22 can be regulated on the gas-liquid contact part 18, thereby accelerating
5 humidification.

[0045]

This can efficiently dehumidify indoor air in summer and efficiently humidify indoor air in winter. Thus, the air
10 humidity regulating method of the present embodiment can regulate a temperature during humidity control, thereby improving humidity-control efficiency.

[0046]

15 (2) The first medium 22 is a mixed solution of water and a solution mainly composed of an ionic liquid. Thus, the viscosity of the ionic liquid serving as a liquid desiccant can be adjusted so as to improve gas-liquid contact. This can effectively exert the water absorbency of the ionic liquid,
20 thereby improving humidity-control efficiency.

[0047]

(3) The ionic liquid is expressed by the chemical formula C^+A^- where C^+ is 1,3-dialkylimidazolium cation and A^- is acid
25 anion. In this way, a proper design selection of an ion pair facilitates ionization. This can improve the water absorbency of the first medium 22 and prevent corrosiveness to metals.

[0048]

(4) The alkyl group of the 1,3-dialkylimidazolium cation is preferably a methyl group or an ethyl group. Acid anion is carboxylate anion, sulfonate anion, or phosphate anion. These ionic liquids particularly have high water absorbency, thereby contributing to improvement of humidity-control efficiency.

[0049]

(5) The ionic liquid in the first medium 22 preferably has a concentration of 60 to 90 mass%, preferably 70 to 80 mass%. In this case, the viscosity of the ionic liquid can be set in a proper range, thereby properly exerting water absorbency based on the ionic liquid.

[0050]

(6) When the ionic liquid has a concentration of 80 mass% and preferably 20 mass% water, the first medium 22 has a saturation vapor pressure of 1.9 kPa or less, preferably 1.8 kPa or less, more preferably 1.2 kPa or less, even more preferably 1.0 kPa or less, and a viscosity of 13 to 21, preferably 14 to 16, mPa·s at 35°C. Thus, the first medium 22 has a proper saturation vapor pressure and a proper viscosity on the gas-liquid contact part 18, thereby effectively exerting the water absorbency of the ionic liquid.

[0051]

(7) The first medium 22 has a flow rate of 0.5 to 3 kg/m²·s, preferably 0.5 to 1.0 kg/m²·s. This can improve contact efficiency between the first medium 22 and the air on the

gas-liquid contact part 18, thereby obtaining high humidity-control efficiency.

[0052]

5 (8) In the regulator 10 used for the air humidity regulating method, the heat exchanging pipe 17 serving as the gas-liquid contact part 18 is disposed in a meandering manner in the gas-liquid contact case 13 that includes the inlet port 14 for feeding air and the outlet port 15 for discharging
10 treated air. The sprinkling pipe 21 that sprays the first medium 22 to the heat exchanging pipe 17 is provided above the heat exchanging pipe 17 and the second medium 24 is passed through the heat exchanging pipe 17.

15 [0053]

Thus, on the gas-liquid contact part 18, a gas-liquid contact is made between the air and the first medium 22. At this point, the second medium 24 regulates the temperature of the first medium 22, thereby improving humidity-control
20 efficiency.

[0054]

(9) The regulator 10 includes the dehumidifier 11 and the humidifier 12 in a pair. The first connecting pipe 26 is
25 provided to guide the first medium 22, which is collected in the container 25 of the dehumidifier 11, to the sprinkling pipe 21 of the humidifier 12. The second connecting pipe 28 is provided to guide the first medium 22, which is collected

in the container 25 of the humidifier 12, to the sprinkling pipe 21 of the dehumidifier 11.

[0055]

5 This can simultaneously improve dehumidification efficiency in the dehumidifier 11 and humidification efficiency in the humidifier 12, thereby increasing energy efficiency in the dehumidifier 11 and the humidifier 12.

10 [0056]

(10) The heat exchanging pipe 17 and the fin 16 are made of metals, preferably aluminum, stainless steel or alloys, even more preferably aluminum or stainless steel, most preferable is aluminum. Thus, heat is efficiently exchanged on the gas-
15 liquid contact part 18, thereby improving water absorbency.

[0057]

[Examples]

20 The embodiment will be more specifically described below in accordance with examples and a comparative example. The values of the parameters cited herein were measured and can be reproduced by the following respective methods:
"Absolute humidity" refers to the total mass of water vapor
25 (in g) per a given mass of dry air (in kg). It can be measured by methods known to the skilled person, for example ISO/TR 18931:2001 (en).

"Saturation vapor pressures" were determined by the method described in: OECD Guidelines for the Testing of Chemicals

(1981): Test No. 104, items 14 - 19 "Static Method", adopted March 23, 2006.

"Flow rate" of solutions were determined with a Coriolis flow meter known to the skilled person.

5 "Viscosity" used herein refers to dynamic viscosity. The measurements of dynamic viscosity were performed at the indicated temperature (for example at 35 °C) by DIN EN ISO 3104 ("multirange capillary"). All the viscosity values given in this specification mean to be those obtained when this
10 method is used.

Density measurements were carried out with DIN 51757, process 4 ("*Biegeschwinger-Verf.*" = "bending vibrator method").

[0058]

15 (Examples 1 to 7 and comparative example 1)

In examples 1 to 7, the air humidity regulating method was tested using the air humidity regulator 10 in Figure 1 under the following conditions:

20 [0059]

[First medium 22]

Example 1: A mixed solution of 80 mass%
1,3-dimethylimidazolium acetate and 20 mass% water, a
saturation vapor pressure of 1.0 kPa at 35°C, and a viscosity
25 of 14 mPa·s at 35°C

Example 2: A mixed solution of 80 mass%

1,3-dimethylimidazolium methylsulfonate and 20 mass% water, a

saturation vapor pressure of 1.9 kPa at 35°C, and a viscosity of 13 mPa·s at 35°C

Example 3: A mixed solution of 80 mass% 1-ethyl-3-methyl-
5 imidazolium diethylphosphate and 20 mass% water, a saturation vapor pressure of 1.8 kPa at 35°C, and a viscosity of 21 mPa·s at 35°C

Example 4: A mixed solution of 80 mass%
10 1,3-dimethylimidazolium propionate and 20 mass% water, a saturation vapor pressure of 1.2 kPa at 35°C, and a viscosity of 16 mPa·s at 35°C

Example 5: A mixed solution of 80 mass% 1-ethyl-3-methyl-
15 imidazolium tetrafluoroborate and 20 mass% water, a saturation vapor pressure of 3.5 kPa at 35°C, and a viscosity of 4 mPa·s at 35°C

Example 6: A mixed solution of 80 mass% 1-ethyl-3-methyl-
20 imidazolium nitrate and 20 mass% water, a saturation vapor pressure of 2.8 kPa at 35°C, and a viscosity of 21 mPa·s at 35°C

Example 7: A mixed solution of a 80 mass% mixture of
25 1,3-dimethylimidazolium chloride and lithium chloride (a mass ratio of 5 to 1) and 20 mass% water, a saturation vapor pressure of 1.9 kPa at 35°C, and a viscosity of 52 mPa·s at 35°C

Comparative example 1: Lithium chloride as an absorbent (an aqueous solution of 33 mass% at 35°C), a saturation vapor pressure of 1.8 kPa at 35°C, and a viscosity of 4 mPa·s at 35°C

5

[0060]

[Dehumidifier 11]

Air as gas subjected to treatment: A temperature of 34°C, an absolute humidity of 19.5 g/kg, and a flow rate of 216 m³/h [In Figure 3(a), L = 0.1 m, H = 0.4 m, and a flow rate of 1.5 m/s were determined and thus $0.1 \times 0.4 \times 1.5 \times 3600 = 216$ m³/h was obtained.]

10

First medium 22: A temperature of 17°C

Second medium 24: A temperature of 17°C, a flow rate of 6 L/min

15

[0061]

[Humidifier 12]

Air as gas subjected to treatment: A temperature of 34°C, an absolute humidity of 19.5 g/kg, and a flow rate of 216 m³/h (as in the case of the dehumidifier 11)

20

First medium 22: A temperature of 50°C

Second medium 24: A temperature of 50°C and a flow rate of 2.5 L/min

25

[0062]

The flow rate of the first medium 22 was changed and an absolute humidity was measured in the air serving as treated gas. Figure 4 shows the measurement results.

[0063]

In comparative example 1, an air humidity regulating method was tested using a plate heat exchanger and a gas-
5 liquid contactor according to the related art. Figure 4 shows the test results.

[0064]

According to the results of Figure 4, in examples 1 to
10 4, the absolute humidity of treated air was reduced to a target humidity or less, that is, 13 g/kg or less when the first medium 22 had a flow rate of 0.5 to 3 kg/m²·s, particularly a low flow rate of 0.5 to 1.0 kg/m²·s. Since L = 0.1 m and W = 0.2 m were determined in Figure 3(a), the
15 passage cross-sectional area of the first medium 22 was 0.02 m². The flow rate was calculated by dividing the flow velocity (kg/s) of the first medium 22 by the passage cross-sectional area of the first medium 22.

20 [0065]

In examples 5 to 7, the absolute humidity was reduced to 13 to 15 g/kg when the first medium 22 had a flow rate of 0.5 to 3 kg/m²·s.

25 [0066]

In comparative example 1, treated air had a high absolute humidity of 14 to 18 g/kg and the absolute humidity did not decrease to 13 g/kg or less when an absorbent had a low flow rate of 2 kg/m²·s or less. This is because the paper

contact member 51 serving as the gas-liquid contact part 18 did not suppress a temperature increase, precluding heat exchange. Moreover, a desiccant in comparative example 1 was highly corrosive to metals and thus the metallic fin 16 or
5 the metallic heat exchanging pipe 17 was unusable.

[0067]

[Relationship between the viscosity of the first medium and a saturation vapor pressure]

10 The viscosity and saturation vapor pressure of the first medium 22 or the absorbent used in examples 1 to 7 and comparative example 1 were measured according to the methods mentioned above. Figure 5 shows the measurement results.

15 [0068]

As shown in Figure 5, the first medium 22 in examples 1 to 4 had a low saturation vapor pressure with a relatively high viscosity. The first medium 22 in examples 5 to 7 had a relatively high saturation vapor pressure with a low
20 viscosity or a high viscosity. The absorbent in comparative example 1 had a low saturation vapor pressure with a low viscosity.

[0069]

25 [Test on the concentration of an ionic liquid in the first medium 22]

An air humidity regulating method was tested as in examples 1 to 4 while the concentration of the ionic liquid in the first medium 22 used in examples 1 to 4 was changed by

5 mass% from 50 mass% to 95 mass% and the first medium 22 had a flow rate of 2 kg/m²·s. Table 1 shows the test results where Good (indicated by "o") represents an absolute humidity not higher than 13 g/kg, Not Good (indicated by "x")

5 represents an absolute humidity not lower than 13 g/kg, and Untested (indicated by "-") represents an untested state with a high viscosity.

[0070]

10 Table 1

	Concentration of ionic liquid in first medium(in "mass %")									
	50	55	60	65	70	75	80	85	90	95
Example 1	x	o	o	o	o	o	o	o	o	o
Example 2	x	x	o	o	o	o	o	o	o	o
Example 3	x	x	o	o	o	o	o	o	o	—
Example 4	x	o	o	o	o	o	o	o	o	—

[0071]

As shown in the test results of Table 1, the ionic liquid in the first medium 22 preferably has a concentration
15 of 60 to 90 mass%.

[0072]

[Humidification test on the humidifier 12]

As in a dehumidification test on the dehumidifier 11 in
20 examples 1 to 4, a humidification test was conducted under the conditions of the humidifier 12. Moreover, the

relationship between a flow rate and an absolute humidity of the first medium 22 was determined. The test results are shown in Figure 6.

5 [0073]

Figure 6 shows the mean value of absolute humidity in examples 1 to 4. A humidification test was similarly conducted in comparative example 1. The test results are shown in Figure 6.

10

[0074]

As shown in Figure 6, when the first medium 22 had a low flow rate in the humidification test, an absolute humidity was higher in examples 1 to 4 than in comparative example 1.

15

[0075]

[The influence of a temperature during humidification by the humidifier 12]

In examples 1 to 4, a humidification test was conducted while the first medium 22 had a flow rate of 2 kg/m²·s and the temperature of the first medium 22 was changed from 30 to 90°C. Table 2 shows the test results where Good (indicated by "o") represents an absolute humidity not lower than 22 g/kg and Not Good (indicated by "x") represents an absolute
20 humidity lower than 22 g/kg.
25

[0076]

Table 2

	Temperature during humidification of first medium (°C)									
	30	35	40	45	50	55	60	70	80	90
Example 1	×	○	○	○	○	○	○	○	○	○
Example 2	×	×	○	○	○	○	○	○	○	○
Example 3	×	×	○	○	○	○	○	○	○	○
Example 4	×	○	○	○	○	○	○	○	○	○

[0077]

5 As shown in Table 2, proper humidification was obtained at a temperature of 40 to 90°C during humidification.

[0078]

10 The embodiment may be changed in a concrete form as follows:

· The first connecting pipe 26 or the second connecting pipe 28 that allows the passage of the first medium 22 may be provided with a heat exchanger for heat exchange with the second medium 24, accelerating the temperature regulation of the first medium 22 through heat exchange with the second medium 24.

[0079]

· The discharge ports 20 of the sprinkling pipe 21 may be varied in opening diameter so as to regulate the droplet size of the first medium 22 flowing from the discharge ports 20.

5

[0080]

· The container 25 in the gas-liquid contact case 13 may be omitted and the first medium 22 may be collected in the lower part of the gas-liquid contact case 13. In this case, one end
10 of the first connecting pipe 26 or the second connecting pipe 28 is connected to the gas-liquid contact case 13.

[Reference Signs List]

[0081]

- 10 regulator
- 5 11 dehumidifier
- 12 humidifier
- 13 gas-liquid contact case
- 13a side wall of gas liquid contact case
- 13b upper wall of gas liquid contact case
- 10 14 inlet port
- 15 outlet port
- 16 fin
- 17 heat exchanging pipe
- 18 gas-liquid contact part
- 15 19 pipe
- 20 discharge port
- 21 sprinkling pipe
- 22 first medium
- 23 receiving pan
- 20 24 second medium
- 25 container
- 26 first connecting pipe
- 27 heat exchanger
- 28 second connecting pipe
- 25 31 valve
- 32 flowmeter
- 33 thermometer
- 51 paper contact members

Claims

[Claim 1]

A gas humidity regulating method comprising:

- 5 feeding gas subjected to treatment from an inlet port
<14> of a gas-liquid contact case <13> into the gas-liquid
contact case <13> while a first medium <22> serving as a
liquid desiccant is disposed on a gas-liquid contact part
<18> and a second medium <24> for temperature regulation is
10 passed through a heat exchanging pipe <17>, the gas-liquid
contact part <18> including the heat exchanging pipe <17> in
the gas-liquid contact case <13> that has the inlet port <14>
for feeding gas subjected to treatment and an outlet port
<15> for discharging treated gas;
15 absorbing water content into the first medium <22> from
the gas subjected to treatment while making a gas-liquid
contact with the first medium <22> on the gas-liquid contact
part <18>; and
 discharging the treated gas from the outlet port <15>.

20

[Claim 2]

The gas humidity regulating method according to claim 1,
wherein the first medium is a mixed solution of water and a
solution mainly composed of an ionic liquid.

25

[Claim 3]

The gas humidity regulating method according to claim 2,
wherein the ionic liquid is expressed by a chemical formula

C⁺A⁻ where C⁺ is 1,3-dialkylimidazolium cation and A⁻ is acid anion.

[Claim 4]

5 The gas humidity regulating method according to claim 3, wherein an alkyl group of the 1,3-dialkylimidazolium cation is a methyl group or an ethyl group, and acid anion is carboxylate anion, sulfonate anion, or phosphate anion.

10 [Claim 5]

 The gas humidity regulating method according to any one of claims 2 to 4, wherein the ionic liquid in the first medium <22> has a concentration of 60 to 90 mass%.

15 [Claim 6]

 The gas humidity regulating method according to any one of claims 2 to 5, wherein when the ionic liquid has a concentration of 80 mass%, the first medium <22> has a saturation vapor pressure of 1.9 kPa or less and a viscosity
20 of 13 to 21 mPa·s at 35°C.

[Claim 7]

 The gas humidity regulating method according to any one of claims 1 to 6, wherein the first medium <22> has a flow
25 rate of 0.5 to 3 kg/m²·s.

[Claim 8]

 A gas humidity regulator <10>, wherein the heat exchanging pipe <17> and a fin <16> are disposed as the gas-

liquid contact part <18> in a meandering manner in the gas-liquid contact case <13> that includes the inlet port <14> for feeding gas subjected to treatment and the outlet port <15> for discharging treated gas, the regulator <10> includes
5 a sprinkling pipe <21> provided above the heat exchanging pipe <17> so as to spray the first medium <22> onto the heat exchanging pipe <17>, and a second medium <24> is passed through the heat exchanging pipe <17>.

10 [Claim 9]

The gas humidity regulator <10> according to claim 8, further comprising a dehumidifier <11> and a humidifier <12> in a pair;

a first connecting pipe <26> that passes the
15 dehumidified first medium <22> between the gas-liquid contact case <13> of the dehumidifier <11> and the sprinkling pipe <21> of the humidifier <12>; and

a second connecting pipe <28> that passes the humidified first medium <22> between the gas-liquid contact case <13> of
20 the humidifier <12> and the sprinkling pipe <21> of the dehumidifier <11>.

[Claim 10]

The gas humidity regulator <10> according to claim 8 or
25 9, wherein the heat exchanging pipe <17> and the fin <16> are made of metals.

[Claim 11]

The gas humidity regulator <10> according to claim 10, wherein the heat exchanging pipe <17> and the fin <16> are made of aluminium or stainless steel.

5

[Claim 12]

The gas humidity regulator <10> according to any one of claims 8 to 11, which is used for the gas humidity regulating method according to any one of claims 1 to 7.

10