

DESCRIPTION

TITLE OF INVENTION WATER GENERATION SYSTEM

TECHNICAL FIELD

[0001]

5 The present invention relates to a water generation system that generates water from the atmosphere.

Background Art

[0002]

10 There have been known water generation systems that use desiccants, which can adsorb and desorb water and allow air to penetrate therethrough, to produce water from atmospheric moisture (for example, Patent Document 1 to Patent Document 3). In these water generation systems, atmospheric moisture is adsorbed by the desiccant, the desiccant is dehumidified by heated dry air, and the heated air humidified by the dehumidification is cooled and condensed to obtain condensation water.

15 CITATION LIST

Patent Documents

[0003]

Patent Document 1: JP 56-37021 A

Patent Document 2: JP 2008-511774 A

20 Patent Document 3: JP 2013-47419 A

SUMMARY OF INVENTION

Technical Problem

[0004]

25 When a major disaster such as a large earthquake occurs, it is not unusual for the water supply to be unavailable. In such a disaster, it would be highly beneficial to have the capability to generate water from the atmosphere. Meanwhile, it is not uncommon for the power supply to be restricted as well in the event of disasters. Therefore, it is desirable to

have a water generation system that can operate with the lowest possible power consumption while still generating the maximum amount of water. In addition, not only during times of disasters but also due to daily shortages of good drinking water worldwide, a water generation system that can generate significant amounts of safe drinking water
5 inexpensively is desirable from this viewpoint.

[0005]

Therefore, it is an object of the present invention to provide a water generation system that can generate a large amount of water from the atmosphere with small power consumption.

10 Solution to Problem

[0006]

The inventor has conceived of a novel water generation system that can generate a large amount of water from the atmosphere with small power consumption by applying various techniques and arrived at the present invention.

15 [0007]

More specifically, the present invention provides the following:

[0008]

(1) A water generation system comprising:

20 a desiccant rotor including an area composed of a porous desiccant capable of adsorbing and desorbing atmospheric moisture while allowing air to pass therethrough;

means for rotating the desiccant rotor;

a temperature-raising heat exchanger provided downstream of the desiccant rotor to heat dehumidified air from the desiccant rotor;

25 a condensing heat exchanger provided downstream of the temperature-raising heat exchanger to cause moist air to condense;

a heat pump connected to the condensing heat exchanger to perform heat exchange with the moist air in the condensing heat exchanger to cool the moist air; and

at least one suction fan that guides outside air into the desiccant rotor,

wherein

the air heated by the temperature-raising heat exchanger is guided into a wet area of the desiccant rotor,

5 the condensing heat exchanger is connected downstream of the wet area, and

the heat pump is connected to the temperature-raising heat exchanger, so that a medium heated by heat exchange in the condensing heat exchanger is supplied to the temperature-raising heat exchanger.

(2) The water generation system according to (1), further comprising a solar water
10 heater connected to the temperature-raising heat exchanger to heat a medium that is to provide heat in the temperature-raising heat exchanger.

(3) The water generation system according to (1) or (2), wherein the desiccant rotor comprises a plurality of areas separated by a moisture-impermeable partition(s).

(4) The water generation system according to (3), wherein the desiccant rotor includes
15 two areas separated by a single moisture-impermeable partition.

(5) The water generation system according to any one of (1) to (4), wherein the suction fan is a first suction fan provided upstream of the desiccant rotor and connected to the desiccant rotor.

(6) The water generation system according to (5), further comprising a pre-cooling heat
20 exchanger provided between the first suction fan and the desiccant rotor.

(7) The water generation system according to (6), further comprising a pipe that supplies a medium heated in the pre-cooling heat exchanger, to an area between the desiccant rotor and the temperature-raising heat exchanger.

(8) The water generation system according to any one of (1) to (7), further comprising
25 a second suction fan provided between the wet area of the desiccant rotor and the condensing heat exchanger to guide heated air from the temperature-raising heat exchanger to the wet area of the desiccant rotor.

(9) The water generation system according to any one of (1) to (8), further comprising a third suction fan provided downstream of the condensing heat exchanger to exhaust air removed of moisture by condensation in the condensing heat exchanger.

5 (10) The water generation system according to any one of (1) to (9), further comprising an air volume damper connected to the temperature-raising heat exchanger downstream of the temperature-raising heat exchanger to adjust the volume of air to be supplied to the desiccant rotor.

(11) The water generation system according to any one of (1) to (10), further comprising a water storage tank provided downstream of the condensing heat exchanger to store water
10 generated by condensation in the condensing heat exchanger.

(12) The water generation system according to (11), further comprising a water filtration filter provided between the condensing heat exchanger and the water storage tank.

Advantageous Effects of Invention

[0009]

15 According to the present invention, a novel water generation system that can generate a large amount of water from the atmosphere with small power consumption is provided. The water generation system according to the present invention can produce good drinking water even in low-temperature and low-humidity environments, which ensures access to good drinking water all the year around, regardless of the season, in
20 various environments worldwide.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

Fig. 1 is a schematic view of a specific and preferable exemplary configuration of a water generation system according to the present invention.

25 Fig. 2 is a schematic view of a specific and preferable exemplary configuration of a temperature-raising heat exchanger according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0011]

Hereinafter, a specific and preferable embodiment of the present invention will be described with reference to the drawings.

[0012]

5 The water generation system shown in Fig. 1 includes a first suction fan 12 that draws in outside air. The first suction fan 12 preferably has an air filter 14 that removes dust from the outside air.

[0013]

10 A pre-cooling heat exchanger 16 is provided downstream of the first suction fan 12 to pre-cool the outdoor air. The pre-cooling heat exchanger 16 is not essential. The pre-cooling heat exchanger 16 is used to pre-cool the outdoor air drawn in by the suction fan 12 to increase its relative humidity and is particularly effective in summer when the outdoor air temperature is high. The pre-cooling heat exchanger 16 exchanges heat between the cooled antifreeze and the suctioned outdoor air. The antifreeze, which has
15 been heated by heat recovery through the heat exchange, is preferably supplied via a pipe 21 between a desiccant rotor 18 and a temperature-raising heat exchanger 20, both of which will be described later. In this case, a pipe 19 between the desiccant rotor 18 and the temperature-raising heat exchanger 20 may be provided as a double pipe as illustrated, so that heat exchange can take place between the heated antifreeze and the outside air that has
20 passed through the desiccant rotor 18, and the outside air which has passed through the desiccant rotor 18 can be heated. Note that a normal plate-type heat exchanger can be used rather than such a double-pipe heat exchanger.

[0014]

25 The desiccant rotor 18 includes an area composed of a porous desiccant capable of adsorbing and desorbing atmospheric moisture while allowing air to pass therethrough (hereinafter referred to as the "desiccant area" for the sake of convenience). Such desiccants themselves are known, examples of which include silica gel-based and titanium

oxide-based materials. The area composed of the desiccant is preferably removably mounted to the rotor for example for routine maintenance. The desiccant rotor 18 preferably has a plurality of desiccant areas separated by a moisture impermeable partition. In the illustrated embodiment, a first desiccant area 18a and a second desiccant area 18b are provided. The partition can be made of a moisture impermeable material such as plastic and metal. It is also preferable that the desiccant rotor 18 itself is also removably mounted, which can be advantageous for maintenance and for replacing the rotor with another desiccant rotor including a different material depending on the situation. In this way, the material of the desiccant can be changed and optimized to suit different conditions, for example when the atmosphere is hot, cold, or low or high in humidity.

[0015]

The desiccant rotor 18 is rotated by means for rotating the desiccant rotor 18. In the illustrated embodiment, the means for rotating the desiccant rotor 18 is an electric motor 22. A rubber belt 23 is wrapped around the rotating shaft of the electric motor 22, and the rubber belt 23 is also wrapped around the outer edge of the desiccant rotor 18, so that as the rotation shaft of the electric motor 22 rotates, the desiccant rotor 18 rotates. The rotation of the desiccant rotor 18 is intermittent or continuous. In the illustrated embodiment, one desiccant rotor 18 is provided, but the water generation can be increased by arranging a plurality of desiccant rotors 18 in parallel and operating the rotors simultaneously.

[0016]

The temperature-raising heat exchanger 20 is connected downstream of the desiccant rotor 18 via the pipe 19. The temperature-raising heat exchanger 20 is used to heat dehumidified air that has passed through the first desiccant area 18a of the desiccant rotor 18. The detailed structure of the temperature-raising heat exchanger 20 will be described later.

[0017]

A solar water heater 24 is connected to the temperature-raising heat exchanger 20. The solar water heater 24 is used to heat a medium that is to exchange heat with the air, which has passed through the desiccant area 18a, in the temperature-raising heat exchanger 20 and provide heat to the air, and a commercially available product can be used. The
5 medium can be water, but antifreeze is preferably used. A solar water heater with a follow-up heating function is also preferable to prepare for weather conditions where sufficient solar heat is not available. A heater may be provided inside the temperature-raising heat exchanger 20 to prepare for weather conditions where heating with the solar water heater 24 is inadequate. However, the solar water heater 24 is not essential and may be omitted
10 when the area of the location where the water generation system is provided is limited.
[0018]

A second suction fan 26 is provided downstream of the temperature-raising heat exchanger 20. The second suction fan guides heated dry air from the temperature-raising heat exchanger 20 to the second desiccant area 18b of the desiccant rotor 18. Note that in
15 the illustrated embodiment, an air volume damper 28 is provided to dampen the volume of the heated dry air from the temperature-raising heat exchanger 20. The volume of the heated dry air can be optimized by the air volume damper 28, depending on the temperature and humidity environment of the outside air and the moisture adsorbing material of the desiccant rotor 18. The temperature-raising heat exchanger 20 is connected
20 to the air volume damper 28, and the air volume damper 28 is connected to the second desiccant area 18b of the desiccant rotor 18 via a pipe 30, and the second desiccant area 18b is connected to the second suction fan 26 via a pipe 31.
[0019]

A condensing heat exchanger 32 is connected downstream of the second suction fan
25 26 via a pipe 34. The condensing heat exchanger 32 is used to cool air humidified by passing through the second desiccant area 18b and cause the air to condense to generate water. A heat pump 38 is connected to the condensing heat exchanger 32 via a refrigerant

pipe 36. The heat pump 38 can use carbon dioxide or a refrigerant R410A or R32 for general air-conditioners as a working refrigerant. In the condensing heat exchanger 32, heat exchange takes place between the refrigerant supplied by the heat pump 38 via the refrigerant pipe 36 and the humidified air, so that the humidified air is cooled, and condensation occurs to generate water. The heat pump 38 is further connected to the temperature-raising heat exchanger 20 via a pipe 40. The refrigerant heated by the heat pump 38 is introduced into the temperature-raising heat exchanger 20 and is used as a part of the medium for heating the air in the temperature-raising heat exchanger 20.

[0020]

Furthermore, an exhaust fan (third suction fan) 42 is connected downstream of the condensing heat exchanger 32. The exhaust fan 42 exhausts the air removed of moisture by the condensation in the condensing heat exchanger 32. A water storage tank 46 is connected to the condensing heat exchanger 32 via a drainpipe 44. Water generated by the condensation in the condensing heat exchanger 32 is collected in the water storage tank 46 via the drainpipe 44. A water filtration filter 48 is preferably provided between the condensing heat exchanger 32 and the water storage tank 46 to filter the water. The water filtration filter 48 can be of a known type, for example, including a hollow fiber membrane, an activated carbon bed, and a water modification layer. The water filtration filter 48 removes impurities from the outside air that could not be eliminated by air filter 14, while also deodorizing, sterilizing, enhancing water clustering, and supplementing minerals to produce safe and palatable drinking water for humans. The water stored in the water storage tank 46 can be used as it is for drinking water and other purposes.

[0021]

One specific preferred embodiment of the temperature-raising heat exchanger 20 has the configuration schematically shown in Fig. 2. The temperature-raising heat exchanger 20 in the specific preferred embodiment is connected with the solar water heater 24 and the heat pump 38. In other words, there are two types of media used for heating the

air. The air receives heat from these two types of heating media, and the heated dry air is supplied to the second desiccant area 18b. In order to allow the function to be achieved, the specific preferred embodiment of the temperature-raising heat exchanger 20 includes two units, as shown schematically in Fig. 2. A first unit, as shown in the left part of Fig. 2, includes a heat exchange tank 50 which is filled with a medium such as antifreeze. A pipe 52 from the solar water heater 24 and a pipe 40 from the heat pump 38 run in the heat exchange tank 50. In addition, a pipe 54, which provides heat to the air, also runs through the heat exchange tank 50. The medium from the solar water heater 24 and the refrigerant from the heat pump 38 both have been heated, and these types of heat are provided to the medium in the heat exchange tank 50, and the medium in turn provides the heat to the medium such as the antifreeze that passes in the pipe 54 provided in the heat exchange tank 50. The medium heated in this way proceeds to a second unit 56, shown in the right part of Fig. 2, and passes in a pipe 58 provided in the unit. Air also passes through the second unit 56, where the air is heated while the medium is cooled by heat exchange as the air passes therethrough. The cooled medium returns to the heat exchange tank 50 in the first unit, shown in the left part of Fig. 2, to be heated again.

[0022]

The operation during water generation will now be described. The white arrows in Fig. 1 indicate the advancing direction of air and the black arrows indicate the direction of the medium for heat exchange (antifreeze or water). The first suction fan 12 is activated to draw in outside air through the air filter 14. The drawn-in outdoor air is pre-cooled by the pre-cooling heat exchanger 16 and then guided to the first desiccant area 18a of the desiccant rotor 18. The first desiccant area 18a is dry and the outdoor air is dehumidified as it passes through the desiccant area 18a and becomes dry air. The dry air is heated by heat exchange in the pipe 19 with the antifreeze which has been heated by heat received from the outdoor air in the pre-cooling heat exchanger 16. Furthermore, the dry air is introduced into the temperature-raising heat exchanger 20. In the temperature-raising heat exchanger

20, the air exchanges heat with the heated antifreeze from the solar water heater 24 and heated. The air also exchanges heat with the heated medium from the heat pump 38 and is further heated.

[0023]

5 The heated dry air is drawn in by the second suction fan 26, and after its air volume is adjusted by the air volume damper 28, the air is guided to the second desiccant area 18b of the desiccant rotor 18 via the pipe 30. The air volume damper 28 is not essential, but the presence of the air volume damper 28 allows the operation mode to be optimized by controlling the air volume damper in conjunction with the temperature-raising heat
10 exchanger 20 under various environmental conditions and requirements, such as atmospheric temperature conditions, water generation cost priority, water generation volume priority, for example when it is preferable to reduce the air volume and increase the temperature (such as when a desiccant material with high adsorption efficiency under low temperature and low humidity that has a high desorption temperature is used), or
15 conversely, when a greater air volume is necessary (such as when a silica material which is sufficiently desorbed at around 50°C is used). The second desiccant area 18b is in a wet state. In other words, in the illustrated state, the first desiccant area 18a is in a dry state, and the second desiccant area 18b is in a wet state. The first desiccant area 18a gradually becomes wet by adsorbing moisture from the outside air. Meanwhile, the second desiccant
20 area 18b is in a wet state but gradually becomes dry as the heated and dried air passes therethrough. After operation for a prescribed period of time, the desiccant rotor 18 is rotated by the electric motor 22 and the first desiccant area 18a, which has become wet, moves to the original location of the second desiccant area 18b and heated dry air passes the location. Meanwhile, the second desiccant area 18b, which has become dry, moves to
25 the original location of the second desiccant area 18a and pre-cooled outdoor air passes through the location. Note that the desiccant rotor 18 may be rotated intermittently or continuously. In this way, an important feature of the present invention is that the air

passing through the second desiccant area 18b is air that has been dried after passing through the first desiccant area 18a. This significantly improves the water generation efficiency, increases the water generation, and saves the required electrical energy compared to the case of using fresh outdoor air (i.e., undried air) as the air passing through the second desiccant area 18b.

[0024]

The heated dry air receives moisture in the second desiccant area 18b and is humidified as it passes through the second desiccant area 18b. The humidified air reaches the condensing heat exchanger 32 via the pipe 34, where the air is cooled by heat exchange with the refrigerant from the heat pump 38. This cooling causes condensation and water is generated. The generated water is stored in the water storage tank 46 after passing through the water filtration filter 48 via the drainpipe 44. Meanwhile, the air dehumidified by the condensation is exhausted by the exhaust fan 42.

[0025]

Meanwhile, the refrigerant heated by the heat pump 38 is introduced into the temperature-raising heat exchanger 20 and is used as part of the medium to provide heat to the air.

[0026]

In the specific preferred embodiment described above, the three suction fans, i.e., the first suction fan 12, the second suction fan 26, and the exhaust fan 42 are provided. Although it is preferable to use the three suction fans in this manner, at least one suction fan needs only be provided and the other one or two suction fans can be omitted. Using at least one suction fan, outside air can be guided to the desiccant rotor 18.

[0027]

The water generation system according to the present invention can generate a large quantity of water with a small amount of electricity by using the solar water heater and the heat pump as well as various heat exchangers. Drinking water can be generated

inexpensively under various conditions, for example when the atmosphere is hot, cold, or low or high in humidity by optimizing the operation conditions and selecting desiccant materials that suit the atmospheric temperature and humidity conditions. Also, the main components include no mechanical parts that are subject to wear and tear, and the most important desiccant rotor 18 is easy to remove and replace, which makes cleaning and replacement work simple, so that the device may have a long useful life. The maintenance cost can also be small.

EXAMPLE

[0028]

10 A prototype water generation system, basically as shown in Figs. 1 and 2, was produced. A commercially available desiccant type small air-conditioner was used as a base unit including a desiccant rotor 18. The pipe 21 and the solar water heater 24 were omitted. The desiccant rotor 18 had a cylindrical structure with a diameter of 200 mm and a thickness of 50 mm and was filled with a titanium dioxide-based material that can be
15 desorbed at a temperature as low as about 50°C, and the area was divided into two parts, alternating between adsorption and desorption sections.

[0029]

 The amount of water obtained from the condensing heat exchanger when 1000 m³ of test air per hour was supplied to the prototype system at a temperature of 30°C with a
20 relative humidity of 60% was as follows. (Power supply used: single-phase 200 V 60 Hz). The tests were conducted twice on September 10 and September 14. The results are shown in Tables 1 and 2 as follows:

[0030]

[Table 1]

Measurement date: September 10, 2021

	Timeframe	Amount of obtained water	Power consumption	Air supply temperature	Relative humidity	Absolute humidity
1	10:30-11:30	4.4 L	2.5 kW	29.7°C	61.5%	16.2 g/kg
2	11:30-13:30	4.6 L	2.5 kW	31.0°C	59.7%	16.9 g/kg
3	12:30-13:30	4.5 L	2.5 kW	31.1°C	58.5%	16.6 g/kg
4	13:30-14:30	4.4 L	2.5 kW	30.2°C	59.8%	16.2 g/kg
5	14:30-15:30	4.5 L	2.5 kW	29.6°C	59.2%	15.5 g/kg
6	15:30-16:30	4.5 L	2.5 kW	29.3°C	61.8%	15.8 g/kg
7	16:30-17:30	4.5 L	2.5 kW	29.6°C	59.6%	15.5 g/kg

Average water generation rate: 4.49 (L/h), 107.8 (L) per 24 hours

Average power consumption: 2.5 (kw/h), 60.0 (kwh) per 24 hours

- 5 Power consumption necessary for 1 liter of water generation: 0.56 (kwh/L)

[0031]

[Table 2]

Measurement date: September 14, 2021

	Timeframe	Amount of obtained water	Power consumption	Air supply temperature	Relative humidity	Absolute humidity
1	10:00-11:00	4.5 L	2.5 kW	30.1°C	60.2%	16.2 g/kg
2	11:00-12:00	4.5 L	2.5 kW	30.3°C	60.1%	16.4 g/kg
3	12:00-13:00	4.5 L	2.5 kW	30.5°C	59.3%	16.3 g/kg
4	13:00-14:00	4.4 L	2.5 kW	30.2°C	60.0%	16.3 g/kg
5	14:00-15:00	4.4 L	2.5 kW	30.1°C	59.9%	16.1 g/kg
6	15:00-16:00	4.4 L	2.5 kW	30.1°C	59.9%	16.1 g/kg
7	16:00-17:00	4.6 L	2.6 kW	30.4°C	60.8%	16.6 g/kg

Average water generation rate: 4.46 (L/h), 107.0 (L) per 24 hours

Average power consumption: 2.51 (kw/h), 60.2 (kwh) per 24 hours

- 10 Power consumption necessary for 1 liter of water generation: 0.56 (kwh/L)

[0032]

When test air at a temperature of 30°C and a relative humidity of 60% was supplied to the prototype system at a rate of 1000 m³ per hour, condensation water was obtained at a rate of 4.5 liters per hour and at a rate of 107.2 liters per 24 hours. The electricity required

for the above was approximately 60 kwh per 24 hours, and the power consumption required for 1 liter of condensation water was 0.56 kwh.

[Reference Signs List]

[0033]

5	12	First suction fan
	14	Air filter
	16	Precooling heat exchanger
	18	Desiccant rotor
	18a	First desiccant area
10	18b	Second desiccant area
	20	Temperature-raising heat exchanger
	21	Pipe
	22	Electric motor
	23	Rubber belt
15	24	Solar water heater
	26	Second suction fan
	28	Air volume damper
	30	Pipe
	31	Pipe
20	32	Condensing heat exchanger
	34	Pipe
	36	Refrigerant Pipe
	38	Heat pump
	40	Pipe
25	42	Exhaust fan
	44	Drainpipe
	46	Water storage tank

	48	Water filtration filter
	50	Heat exchange tank
	52	Pipe
	54	Pipe
5	56	Second unit of temperature-raising heat exchanger 20
	58	Pipe

CLAIMS

[Claim 1]

A water generation system comprising:

5 a desiccant rotor including an area composed of a porous desiccant capable of adsorbing and desorbing atmospheric moisture while allowing air to pass therethrough; means for rotating the desiccant rotor;

a temperature-raising heat exchanger provided downstream of the desiccant rotor to heat dehumidified air from the desiccant rotor;

10 a condensing heat exchanger provided downstream of the temperature-raising heat exchanger to cause moist air to condense;

a heat pump connected to the condensing heat exchanger to perform heat exchange with the moist air in the condensing heat exchanger to cool the moist air; and

at least one suction fan that guides outside air into the desiccant rotor,

wherein

15 the air heated by the temperature-raising heat exchanger is guided into a wet area of the desiccant rotor,

the condensing heat exchanger is connected downstream of the wet area, and

20 the heat pump is connected to the temperature-raising heat exchanger, so that a medium heated by heat exchange in the condensing heat exchanger is supplied to the temperature-raising heat exchanger.

[Claim 2]

The water generation system according to claim 1, further comprising a solar water heater connected to the temperature-raising heat exchanger to heat a medium that is to provide heat in the temperature-raising heat exchanger.

25 [Claim 3]

The water generation system according to claim 1 or 2, wherein the desiccant rotor comprises a plurality of areas separated by a moisture-impermeable partition(s).

[Claim 4]

The water generation system according to claim 3, wherein the desiccant rotor includes two areas separated by a single moisture-impermeable partition.

[Claim 5]

5 The water generation system according to any one of claims 1 to 4, wherein the suction fan is a first suction fan provided upstream of the desiccant rotor and connected to the desiccant rotor.

[Claim 6]

10 The water generation system according to claim 5, further comprising a pre-cooling heat exchanger provided between the first suction fan and the desiccant rotor.

[Claim 7]

The water generation system according to claim 6, further comprising a pipe that supplies a medium heated in the pre-cooling heat exchanger, to an area between the desiccant rotor and the temperature-raising heat exchanger.

15 [Claim 8]

The water generation system according to any one of claims 1 to 7, further comprising a second suction fan provided between the wet area of the desiccant rotor and the condensing heat exchanger to guide heated air from the temperature-raising heat exchanger to the wet area of the desiccant rotor.

20 [Claim 9]

The water generation system according to any one of claims 1 to 8, further comprising a third suction fan provided downstream of the condensing heat exchanger to exhaust air removed of moisture by condensation in the condensing heat exchanger.

[Claim 10]

25 The water generation system according to any one of claims 1 to 9, further comprising an air volume damper connected to the temperature-raising heat exchanger downstream of the temperature-raising heat exchanger to adjust the volume of air to be

supplied to the desiccant rotor.

[Claim 11]

The water generation system according to any one of claims 1 to 10, further comprising a water storage tank provided downstream of the condensing heat exchanger to
5 store water generated by condensation in the condensing heat exchanger.

[Claim 12]

The water generation system according to claim 11, further comprising a water filtration filter provided between the condensing heat exchanger and the water storage tank.