US 20150137396A1

(19) United States
(12) Patent Application Publication
Aramaki et al.
(10) Pub. No.: US 2015/0137396 A1
(43) Pub. Date: May 21, 2015

(54) HUMIDIFICATION UNIT, HUMIDIFICATION METHOD, AND HUMIDIFICATION SYSTEM

(71) Applicant: SINNIHON BIFUU CO., LTD, Osaka (JP)

(72) Inventors: Dai Aramaki, Osaka (JP); Yoshinobu Murakami, Kyoto (JP); Shinsuke Ohara, Shiga (JP); Hiroshi Nagasawa, Kanagawa (JP)

(73) Assignee: SINNIHON BIFUU CO., LTD., Osaka (JP)

(21) Appl. No.: 14/404,766

(22) PCT Filed: May 30, 2013

(86) PCT No.: PCT/JP2013/065071
§ 371 (c)(1),
(2) Date: Dec. 1, 2014

(30) Foreign Application Priority Data

Jun. 1, 2012 (JP) 2012-126291

Publication Classification

(51) Int. Cl.
F24F 6/18 (2006.01)

(52) U.S. Cl.
CPC *F24F 6/18* (2013.01)

(57) ABSTRACT

The present invention provides a humidifying unit, a humidification method, and a humidification system, whereby the efficiency of diffusing water vapor into the air, the absorption amount (absolute humidity), and the water supply utilization can be enhanced.

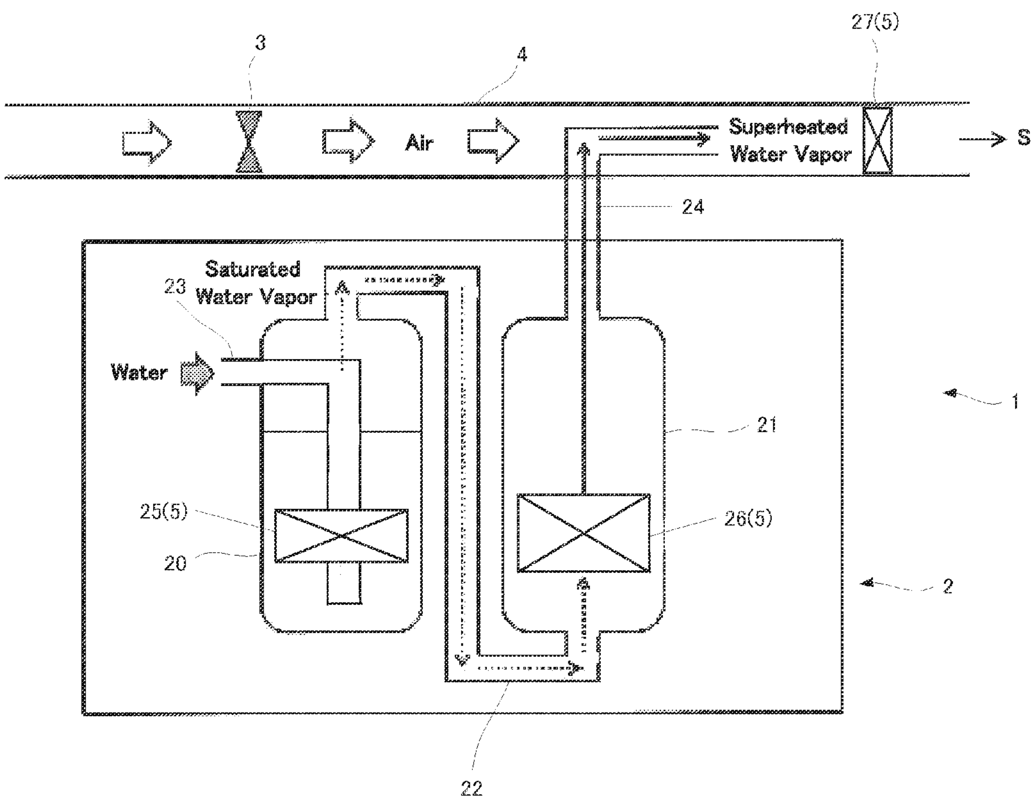


Fig. 1

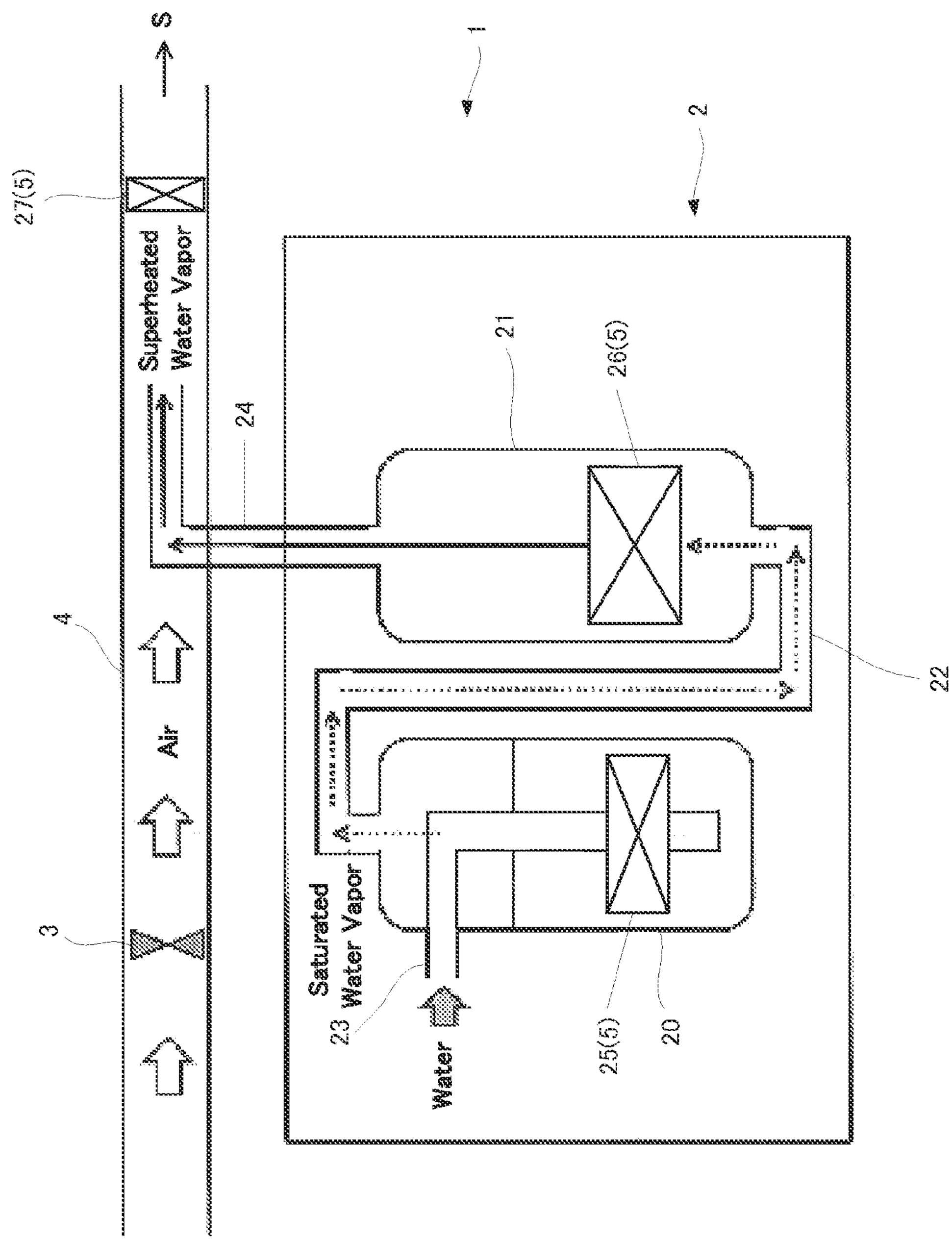

S
1
2
27(5)
Superheated Water Vapor
21
26(5)
24
4
Air
22
3
Saturated Water Vapor
23
Water
25(5)
20

Fig. 2

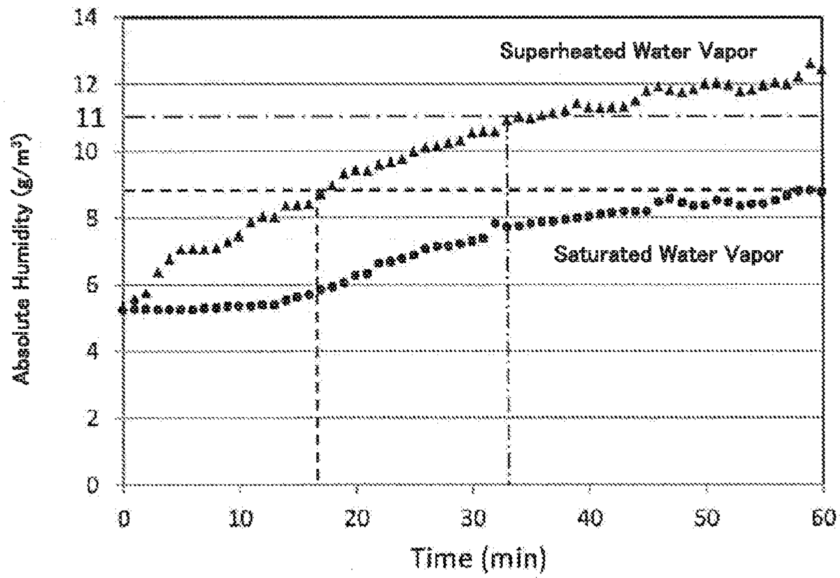

Superheated Water Vapor
Saturated Water Vapor
Absolute Humidity (g/m³)
Time (min)
0
2
4
6
8
10
11
12
14
0
10
20
30
40
50
60

Fig. 3

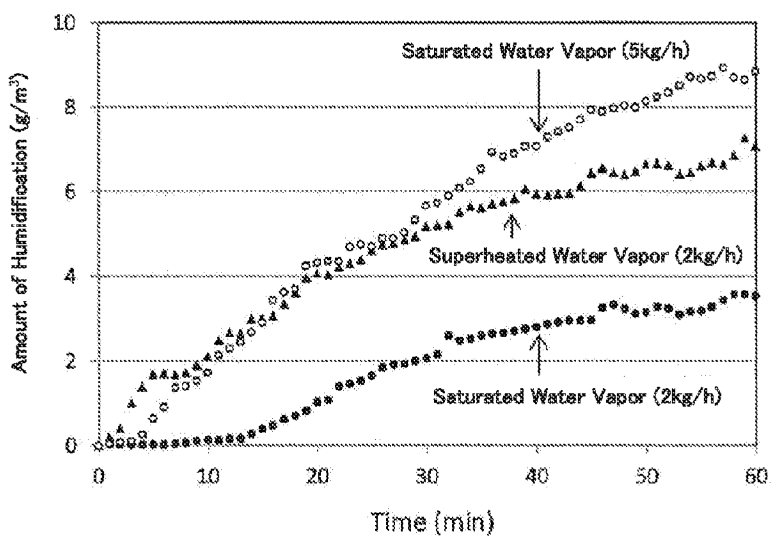

Saturated Water Vapor (5kg/h)
Superheated Water Vapor (2kg/h)
Saturated Water Vapor (2kg/h)
Amount of Humidification (g/m³)
Time (min)
0
2
4
6
8
10
0
10
20
30
40
50
60

Fig. 4

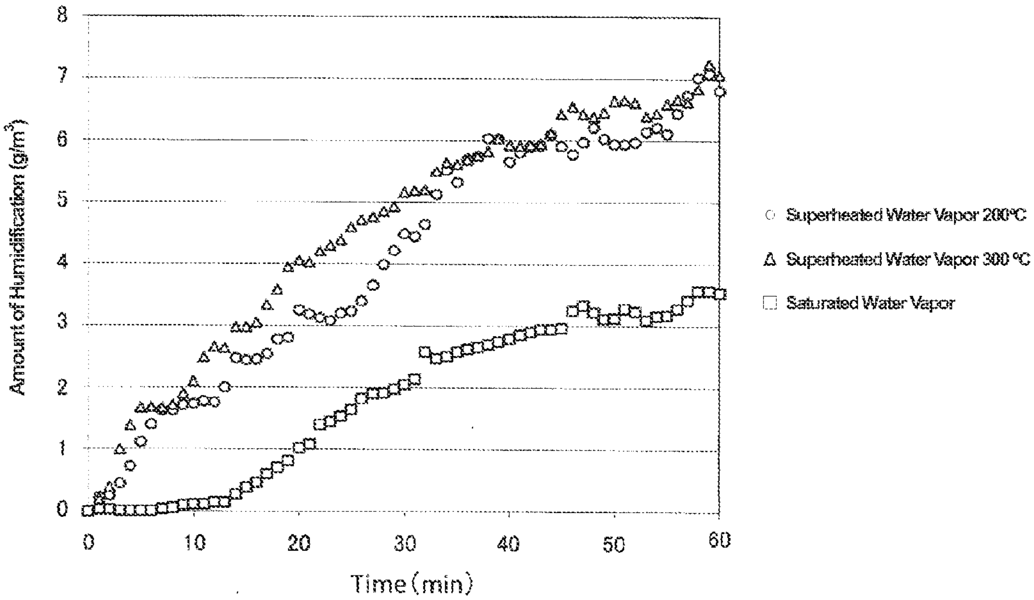

Amount of Humidification (g/m³)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
Time (min)
Superheated Water Vapor 200°C
Superheated Water Vapor 300 °C
Saturated Water Vapor

Fig. 5

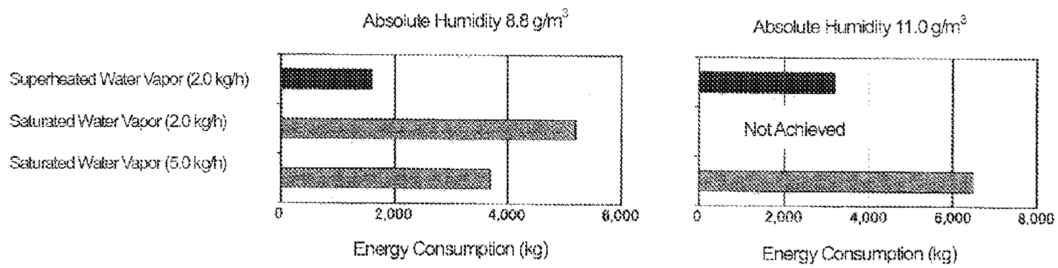
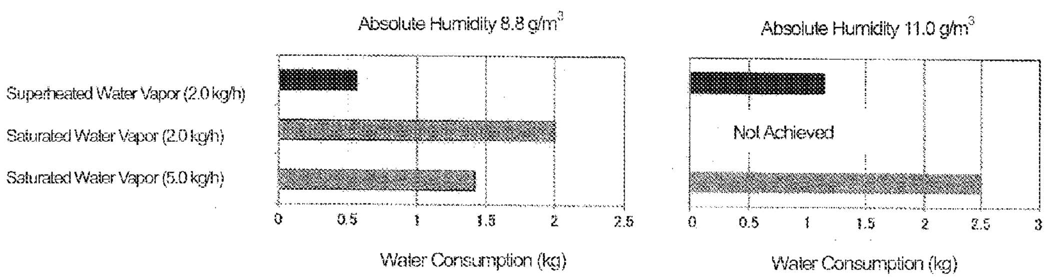

Absolute Humidity 8.8 g/m3
Superheated Water Vapor (2.0 kg/h)
Saturated Water Vapor (2.0 kg/h)
Saturated Water Vapor (5.0 kg/h)
0
2,000
4,000
6,000
Energy Consumption (kg)
Absolute Humidity 11.0 g/m3
Not Achieved
0
2,000
4,000
6,000
8,000
Energy Consumption (kg)

Fig. 6


Absolute Humidity 8.8 g/m3
Superheated Water Vapor (2.0 kg/h)
Saturated Water Vapor (2.0 kg/h)
Saturated Water Vapor (5.0 kg/h)
0
0.5
1
1.5
2
2.5
Water Consumption (kg)
Absolute Humidity 11.0 g/m3
Not Achieved
0
0.5
1
1.5
2
2.5
3
Water Consumption (kg)

HUMIDIFICATION UNIT, HUMIDIFICATION METHOD, AND HUMIDIFICATION SYSTEM

CITATION LIST

Patent Document

[0001] Patent Document 1: Japanese Patent No. 2631674

SUMMARY OF INVENTION

Technical Problem

[0002] However, in conventional humidification systems, a humidifying unit sprays saturated water vapor for humidification. Saturated water vapor typically contains "steam," which is a large amount of minuscule water droplets as evidenced by the white smoke, which cannot be seen in gas under ordinary circumstances. Because of its large particle size, steam is not necessarily diffused into air efficiently, and saturated water vapor thus has a disadvantage in that it is not uniformly absorbed into air. When the air temperature is low, particularly during the winter season, the jets of saturated water vapor (steam) are cooled by the air and condensed into water droplets, which are not absorbed into the air. This leads to a decrease in the amount of saturated water vapor absorbed into the air (absolute humidity). Thus, it is difficult to sufficiently humidify, for example, hospitals to prevent droplet infections such as influenza. Further, because particles having a large particle size require a long vaporization absorption distance (the distance from the point at which the water vapor is sprayed into air to the point at which the water vapor is absorbed into the air), saturated water vapor (steam) impinges against steam-spray nozzle pipes or the like, and water droplets (i.e., condensed water) are adhered to the nozzle pipes or the like. Accordingly, supplied water is not effectively utilized, and even scales and condensed water discharge must be addressed. Moreover, because dust adhered to the surface of condensed water is a cause of pollution, becoming a nest for bacteria and saprophytes, hygiene control of the expelled saturated water vapor is also required. In addition to the above-mentioned steam humidification systems, evaporative humidification systems and water spray humidification systems are also available. Although evaporative and water spray humidification systems require less energy and less operation cost, these systems are disadvantageous in terms of, for example, poor humidification efficiency, room temperature decrease caused by vaporization heat, fine particulate pollution caused by the precipitates of impurities in water, and mold odor.

[0003] An object of the present invention is to provide a humidifying unit, a humidification method, and humidification system that can enhance the efficiency of water vapor diffusion into air, absorption amount of water vapor (absolute humidity), and water supply utilization, and that can solve the above-described problems.

Solution to Problem

[0004] The object of the present invention is achieved by a humidifying unit that supplies superheated water vapor of 130° C. or more to air, to thereby humidify the air. Although this is described in detail later, the temperature of the superheated water vapor is preferably 130° C. or more, more preferably 170° C. or more, still more preferably 200° C. or more, and further still more preferably 300° C. or more.

[0005] In a preferred embodiment of the present invention, the humidifying unit comprises: a water-vapor-generating unit provided in the first heating chamber, the water-vapor-generating unit being configured to heat water supplied to the first heating chamber to generate water vapor; and a superheated-water-vapor-generating unit provided in the second heating chamber, the superheated-water-vapor-generating unit being configured to heat the water vapor supplied to the second heating chamber from the water-vapor-generating unit to thereby generate superheated water vapor.

[0006] The object of the present invention is also achieved by a humidification method for supplying superheated water vapor of 130° C. or more to air, to humidify the air. Although this is described in detail later, the temperature of the superheated water vapor is preferably 130° C. or more, more preferably 170° C. or more, still more preferably 200° C. or more, and further still more preferably 300° C. or more.

[0007] The object of the present invention is also achieved by a humidification system comprising: a blower fan for sending air; a duct for directing the air from the blower fan to an indoor space; a humidifying unit for supplying superheated water vapor to the air in the duct; and a control unit for controlling the humidifying unit to adjust the temperature and the amount of the superheated water vapor supplied to the air in the duct.

[0008] In a preferred embodiment of the present invention, the humidification system further comprises a heating unit for heating the humidified air in the duct.

[0009] In a preferred embodiment of the present invention, the humidification system further comprises: a hygrometer for measuring the humidity of an indoor space; and a thermometer for measuring the temperature of an indoor space, wherein the control unit controls the humidifying unit and the heating unit to adjust the temperature, the relative humidity, and the absolute humidity of the indoor space on the basis of the temperature and humidity of the indoor space measured by the thermometer and the hygrometer.

Advantageous Effects of Invention

[0010] Because the present invention can enhance the efficiency of diffusing water vapor into air and increase the amount of water vapor to be absorbed into air (absolute humidity), the present invention enables prompt and uniform absorption of sufficient water vapor into air. Consequently, the present invention can provide a sufficient amount of humidification to an indoor space of, for example, hospitals in a short period of time to prevent droplet infections such as influenza. Further, because water supply utilization can be enhanced, the present invention can suppress the formation of scales and condensed water. Thus, the present invention can diminish the need to address the scales and condensed water discharge, and can also prevent the development of bacteria or saprophytes in the humidifying unit to thereby enable discharge of hygienic water vapor from the humidifying unit.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a schematic simplified diagram showing a basic configuration of the humidification system according to an embodiment of the present invention.

[0012] FIG. **2** is a graph showing the change in absolute humidity over time.

[0013] FIG. **3** is a graph showing the change in humidification amount over time.

[0014] FIG. **4** is a graph showing the change in humidification amount over time for each temperature of superheated water vapor used for humidification.

[0015] FIG. **5** is a graph showing the difference of energy consumption required in humidification between saturated water vapor and superheated water vapor.

[0016] FIG. **6** is a graph showing the difference of water consumption required in humidification between saturated water vapor and superheated water vapor.

DESCRIPTION OF EMBODIMENTS

[0017] Hereinafter, an embodiment of the present invention is described with reference to the attached drawings. FIG. **1** is a schematic simplified diagram showing a basic configuration of a humidification system **1** according to an embodiment of the present invention. As used herein, the term "superheated water vapor" refers to water vapor obtained by further heating, at a certain pressure, water vapor (saturated water vapor) generated by evaporation at its boiling point determined at the certain pressure, and also refers to water vapor heated, at atmospheric pressure without applying additional pressure, to a temperature exceeding 100° C., which is the boiling point of water at atmospheric pressure.

[0018] In this embodiment of the present invention, the humidification system **1** for supplying humidified air to an indoor space S to control the humidity of the indoor space S comprises: a blower fan **3** for sending air; a duct **4** for directing the air from the blower fan **3** to the indoor space S; and a humidifying unit **2** for supplying superheated water vapor to the air in the duct **4**.

[0019] The humidifying unit **2** comprises a hermetically sealed first heating chamber **20** and a hermetically sealed second heating chamber **21**, and the chambers **21** and **22** are connected through a water vapor flow channel **22**. To the first heating chamber **20**, a water feed channel **23** is connected, and water is supplied to the first heating chamber **20** from a water-pooling tank (not shown) through the water feed channel **23**. To the second heating chamber **21**, a superheated water vapor flow channel **24** is connected. The head of the superheated water vapor flow channel **24** extends inside the duct **4**, and superheated water vapor of 130° C. or more generated in the second heating chamber **21** is supplied to the air inside the duct **4** through the superheated water vapor flow channel **24**.

[0020] The first heating chamber **20** and the second heating chamber **21** comprise a water-vapor-generating unit **25** and a superheated-water-vapor-generating unit **26**, respectively. In the first heating chamber **20**, the water-vapor-generating unit **25** heats water supplied from the tank to thereby generate saturated water vapor. In the second heating chamber **21**, the superheated-water-vapor-generating unit **26** heats the saturated water vapor supplied from the first heating chamber **20** through the water vapor flow channel **22** to thereby generate superheated water vapor.

[0021] The water-vapor-generating unit **25** and the superheated-water-vapor-generating unit **26** are each configured by using an electrical resistance heater formed of a porous metal sheet, for which the electrical resistance heater **5** disclosed in Japanese patent No. 3813234, for example, can preferably be used. The humidifying unit disclosed, for example, in Japanese patent No. 4684823 can preferably be used as the above-described humidifying unit **2** for generating superheated water vapor.

[0022] When a heating power source (not shown) supplies power to the electrical resistance heater **5** to allow temperature control, in the first heating chamber **20**, water fed to the bottom of the first heating chamber **20** from the water feed channel **23** efficiently exchanges heat with the heated electrical resistance heater **5** when passing therethrough. Thus, the water is heated in a short period of time to transform into saturated water vapor. At this stage, the amount of heat to be generated by the electrical resistance heater **5** (the amount of power supplied to the electrical resistance heater **5**) can be controlled to adjust the temperature and the amount of saturated water vapor to be generated. In the second heating chamber **21**, the saturated water vapor fed to the second heating chamber **21** from the water vapor flow channel **22** efficiently exchanges heat with the electrical resistance heater **5** when passing therethrough. Thus, the saturated water vapor is heated in a short period of time to transform into superheated water vapor. At this stage, the amount of heat to be generated by the electrical resistance heater **5** (the amount of power supplied to the electrical resistance heater **5**) can be controlled to adjust the temperature and the amount of superheated water vapor to be generated. The temperature of superheated water vapor is, for example, preferably 130° C. or more, more preferably 170° C. or more, still more preferably 200° C. or more, and further still more preferably 300° C. or more. As described above, it is sufficient if superheated water vapor has a temperature of more than 100° C. at normal atmospheric pressure; however, when the temperature of superheated water vapor is slightly more than its boiling point, the temperature often drops to the boiling point, which may undermine the advantage of using superheated water vapor. Experiments revealed that when superheated water vapor has a temperature of 130° C. or more, there is little generation of "steam," which is minuscule droplets of water contained in water vapor and observed at a temperature above the saturation point; thus, superheated water vapor having a temperature of 130° C. or more is a favorable condition for the present invention. As described later, superheated water vapor having a temperature of 170° C. or more can prevent the proliferation of *Geobacillus stearothermophilus*, which is a microorganism (bacterium) showing high resistance to heat and humidity; i.e., superheated water vapor has a sterilizing effect on an indoor space S, thereby providing safer air-conditioned environments. As described later, superheated water vapor having a temperature of 200° C. or more can provide an excellent amount of humidification to the indoor space S. Superheated water vapor having a higher temperature is suitable for humidification because the superheated water vapor transforms into gaseous water molecules. However, the temperature of superheated water vapor is preferably set to about up to 450° C. for the following reasons: water vapor fully transforms into gaseous water molecules at 300° C. or more; and it is not effective for an air-conditioning system to raise the temperature more than necessary, from the viewpoint of energy consumption.

[0023] The blower fan **3** sends air to the indoor space S, and the air from the blower fan **3** absorbs, in the duct **4**, superheated water vapor that has been generated in the humidifying unit **2** and directed to the duct **4** through the superheated water vapor flow channel **24** so that the air is humidified. The humidified air is blown into the indoor space S from the air outlet, and the indoor space S is thus humidified. At this stage, the amount of saturated water vapor generated in the water-vapor-generating unit **25** and the amount of superheated water vapor generated in the superheated-water-vapor-generating unit **26** can be controlled to adjust the amount of humidification (absolute humidity) to be provided to the indoor space S.

[0024] In this embodiment of the present invention, a heating unit **27** is provided in front of the air outlet in the duct **4**. The heating unit **27** heats the humidified air to be blown into the indoor space S to control the temperature of the humidified air. This enables control of the temperature and the relative humidity of the indoor space S. This heating unit **27** is also preferably configured by using the electrical resistance heater **5** disclosed in the aforementioned Japanese patent No. 3813234.

[0025] In this embodiment of the present invention, although they are not shown, a hygrometer for measuring the humidity of the indoor space S and a thermometer for measuring the temperature of the indoor space S are provided in the indoor space S. The hygrometer and thermometer are connected to a control unit (not shown), and controlled together with the water-vapor-generating unit **25**, the superheated-water-vapor-generating unit **26**, and the heating unit **27**. Thus, in the humidification system **1** according to this embodiment of the present invention, the control unit enables automatic triple control of the temperature, relative humidity, and absolute humidity of the indoor space S on the basis of the temperature and humidity of the indoor space S.

[0026] In the humidification system **1** and humidifying unit **2** configured as described above, superheated water vapor is supplied to the air to be sent to the indoor space S so that the indoor space S is humidified. Saturated water vapor typically contains "steam," i.e., a large amount of minuscule droplets of water, as evidenced by the white smoke, which is not observed in gas. Comparatively, superheated water vapor has a higher temperature than saturated water vapor, and is in a gaseous molecular state without containing steam. Thus, superheated water vapor can be diffused into air more efficiently than saturated water vapor. Further, superheated water vapor has a shorter vaporization absorption distance than saturated water vapor, and is easily absorbed into air; thus, superheated water vapor can be absorbed into air in a larger amount than saturated water vapor (absolute humidity). This enables prompt and uniform absorption of a sufficient amount of water vapor into air, thereby establishing in a short period of time a humid environment satisfactory to prevent droplet infections such as influenza in an indoor space S, for example, in a hospital.

[0027] Superheated water vapor is considered to be basically water in a gas phase. Thus, unlike saturated water vapor containing "steam," which is not in a gas phase but minuscule droplets of water liquid, superheated water vapor mixes with air and increases the humidity promptly. Superheated water vapor can also inhibit the development of condensed water, which builds up in the duct **4** or in the superheated water vapor flow channel **24**, because superheated water vapor does not transform into water droplets from "steam" and diffuse into air. This increases the water supply utilization, thereby requiring a smaller amount of water to be supplied to the humidifying unit **2**, increasing the energy efficiency, diminishing the need to address scales and condensed water discharge, and preventing the development of bacteria and saprophytes in the humidifying unit to discharge hygienic water vapor from the humidifying unit.

[0028] The present inventors conducted experiments (humidification experiments) to examine the difference in humidifying effect between the humidification achieved by supplying saturated water vapor-containing air to an indoor space S and the humidification achieved by supplying superheated water vapor-containing air to an indoor space S. Superheated water vapor was generated by a humidifying unit **2** comprising a water-vapor-generating unit **25** and a superheated-water-vapor-generating unit **26**, which are configured as described above. Saturated water vapor was generated by using only a water-vapor-generating unit **25** configured as described above (the electrical resistance heater **5** disclosed in Japanese patent No. 3813234).

Humidifying Effect

[0029] FIGS. **2** to **4** show the results of the humidification experiments on the absolute humidity and the amount of humidification in the indoor space S. The indoor space S is a closed space having a volume of 60 m^3 (room temperature: about 18° C.), and provided with 10 temperature-and-humidity data loggers (SK-L200THIIa, Sato Keiryoki Mfg. Co., Ltd.) that constantly measured and recorded the change in temperature and humidity at 10 measurement points in the indoor space S.

[0030] FIG. **2** shows the change in the absolute humidity of the indoor space S over time under conditions in which saturated water vapor and superheated water vapor (temperature: 300° C.) were individually generated at a rate of 2 kg/h, and separately humidified the indoor space S. FIG. **2** reveals that despite the generation of water vapor in the same amount, there is a difference in absolute humidity even at the beginning of humidification between the humidification by saturated water vapor and the humidification by superheated water vapor, and that one hour after from the start of humidification, humidification by superheated water vapor achieved an absolute humidity of 12.6 g/m^3, which is compared to the absolute humidity of 8.8 g/m^3 achieved by the humidification by saturated water vapor; therefore, there is a significant difference between them. Moreover, the absolute humidity (8.8 g/m^3) achieved with one-hour humidification by saturated water vapor was achieved with about 17-minute humidification by superheated water vapor. Furthermore, humidification by superheated water vapor achieved the absolute humidity of 11.0 g/m^3, which is considered to be effective to prevent influenza transmission, 35 minutes after the start of humidification, whereas humidification by saturated water vapor failed to achieve the absolute humidity of 11.0 g/m^3 even after one-hour humidification. As such, the humidification by superheated water vapor can enable absorption of a sufficient amount of water vapor into air, and can achieve a higher absolute humidity than the humidification by saturated water vapor.

[0031] FIG. **3** shows the change in the amount of humidification in the indoor space S over time under conditions in which saturated water vapor and superheated water vapor (temperature: 300° C.) individually humidified the indoor space (S). In FIG. **3**, "●" indicates the amount of humidification achieved by generating saturated water vapor at a rate of 2 kg/h to humidify the indoor space S; "○" indicates the amount of humidification achieved by generating saturated water vapor at a rate of 5 kg/h to humidify the indoor space S; and "▲" indicates the amount of humidification achieved by generating superheated water vapor at a rate of 2 kg/h to humidify the indoor space S. FIG. **3** reveals that the humidification by superheated water vapor generated at a rate of 2 kg/h achieved a higher amount of humidification than the humidification by saturated water vapor at the same rate, and also reveals that 30 minutes after from the start of humidification, the humidification by superheated water vapor generated at a rate of 2 kg/h achieved the same amount of humidification as the humidification by saturated water vapor generated at a rate of 5 kg/h. This shows that the humidification by superheated water vapor is faster than the humidification by saturated water vapor in terms of humidifying rate, and also achieves a higher amount of humidification per amount of water supplied (water supply utilization).

[0032] FIG. **4** shows the change in the amount of humidification in the indoor space S over time for each temperature of superheated water vapor used for humidification. In FIG. **4**, "o" indicates the amount of humidification achieved by generating superheated water vapor of 200° C. to humidify the indoor space S; "Δ" indicates the amount of humidification achieved by generating superheated water vapor of 300° C. to humidify the indoor space S; and "□" indicates the amount of humidification achieved by generating saturated water vapor to humidify the indoor space S. In every case, water vapor was generated at a rate of 2 kg/h. FIG. **4** reveals that the humidification by superheated water vapor of 200° C. is excellent because it achieved the same amount of humidification as the humidification by superheated water vapor of 300° C. Further, the humidification by superheated water vapor of 200° C. and the humidification by superheated water vapor of 300° C. both achieved a considerably higher amount of humidification than the humidification by saturated water vapor immediately after the start of humidification; this also shows that the humidification by superheated water vapor is faster than the humidification by saturated water vapor in terms of humidifying rate, because superheated water vapor mixes with air and increases the temperature promptly.

Energy Efficiency and Water Supply Utilization

[0033] FIGS. **5** and **6** show evaluations of the energy consumption and water consumption required to achieve a desired absolute humidity by the humidification by saturated water vapor and by the humidification by superheated water vapor, on the basis of the experiment results. The left-hand graph of FIG. **5** shows a comparison of the energy consumption required to achieve an absolute humidity of 8.8 g/m^3, which was achieved by saturated water vapor in one hour. The right-hand graph of FIG. **5** shows a comparison of the energy consumption required to achieve an absolute humidity of 11.0 g/m^3, which is considered to be effective to prevent influenza transmission. The left-hand graph of FIG. **6** shows a comparison of the water consumption required to achieve an absolute humidity of 8.8 g/m^3, and the right-hand graph of FIG. **6** shows the water consumption required to achieve an absolute humidity of 11.0 g/m^3. In actual measurement of energy consumption, the specific heat of water, the latent heat of vaporization of water, and the specific heat of water vapor are respectively defined as 4.2 kJ/kg·K, 2,250 kJ/kg, and 2.1 kJ/kg·K.

[0034] As shown in FIG. **5**, the energy consumption required in humidification for one hour by saturated water vapor generated at a rate of 2 kg/h, i.e., the power supplied to the water-vapor-generating unit **25** (electrical resistance heater **5**), is about 5,200 kJ. Comparatively, although the humidification by superheated water vapor requires not only power to be supplied to the water-vapor-generating unit **25** (electrical resistance heater **5**) for generating saturated water vapor but also power to be supplied to the superheated-water-vapor-generating unit **26** (electrical resistance heater **5**) for generating superheated water vapor, humidification by superheated water vapor generated at a rate of 2 kg/h for about 17 minutes achieved substantially the same amount of humidification as that of humidification by saturated water vapor for one hour, consuming energy of about 3,680 kJ.

[0035] Humidification by saturated water vapor generated at a rate of 5 kg/h achieves an absolute humidity of 8.8 g/m^3 in 17 minutes from the start of humidification, and achieves an absolute humidity of 11.0 g/m^3 in 30 minutes; thus, humidification by saturated water vapor produces substantially the same humidifying effect as humidification by superheated water vapor generated at a rate of 2 kg/h until an absolute humidity of 11.0 g/m^3 is achieved. However, as shown in FIG. **5**, to achieve each of the absolute humidity 8.8 g/m^3 and 11.0 g/m^3, humidification by saturated water vapor generated at a rate of 5 kg/h required energy consumption of about 3,680 kJ and about 6,500 kJ, respectively, whereas humidification by superheated water vapor generated at a rate of 2 kg/h required energy consumption of about 1,590 kJ and about 3,190 kJ, respectively. As such, FIG. **5** reveals that humidification by superheated water vapor requires less energy consumption than humidification by saturated water vapor to achieve substantially the same amount of humidification as that achieved by humidification by saturated water vapor; thus, humidification by superheated water vapor is more energy efficient than humidification by saturated water vapor.

[0036] FIG. **6** shows water consumption comparisons. To achieve an absolute humidity of 8.8 g/m^3, humidification by saturated water vapor generated at a rate of 2 kg/h and 5 kg/h required about 2.0 kg and about 1.4 kg of water consumption, respectively, whereas humidification by superheated water vapor generated at a rate of 2 kg/h required merely about 0.57 kg of water consumption. To achieve an absolute humidity of 11.0 g/m^3, humidification by saturated water vapor generated at a rate of 5 kg/h required about 2.5 kg of water consumption, whereas humidification by superheated water vapor generated at a rate of 2 kg/h required merely about 1.1 kg of water consumption. As such, FIG. **6** reveals that humidification by superheated water vapor requires less water consumption than humidification by saturated water vapor to achieve substantially the same amount of humidification as that achieved by humidification by saturated water vapor; thus, humidification by superheated water vapor can achieve a higher amount of humidification than humidification by saturated water vapor, per amount of water supplied (water supply utilization).

[0037] As noted above, humidification by superheated water vapor is faster than humidification by saturated water vapor in terms of humidifying rate, achieves a higher absolute humidity, achieves substantially the same amount of humidification as that achieved by humidification by saturated water vapor by consuming less energy and water, and shows excellent energy efficiency and water supply utilization.

Measurement of Water Hardness

[0038] In humidification experiments 1 and 2, the total hardness of water (Ca^{2+} and Mg^{2+}) obtained by ice-cooling the superheated water vapor that has been discharged from the humidifying unit **2** and the total hardness of raw water (tap water) supplied to the humidifying unit **2** were measured by a method using chelate. The results show that the raw water (tap water) had a total hardness of 65 ppm, whereas the water obtained by ice-cooling the superheated water vapor had a total hardness below the detection limit (0 ppm).

Sterilization Test

[0039] Sterile filter paper was impregnated with *Geobacilius stearothermophilus* (40×10^6 C.F.U., ACTT, registered trademark, 7953), exposed to superheated water vapor, and then immersed in 5 mL of sterile SCDLP medium (Daigo), followed by culturing at 50° C. for 48 hours; afterward, the proliferation of the bacterium was evaluated. The results show that when *Geobacillus stearothermophilus*, which is a microorganism (bacterium) showing high resistance to heat and humidity, was exposed to superheated water vapor at 120° C., 140° C., and 170° C., the proliferation of the bacteria was observed in the paper exposed to superheated water vapor of 120° C. and 140° C.; however, the paper exposed to superheated water vapor of 170° C. showed no proliferation of *Geobacillus stearothermophilus*, thus confirming the sterilizing effect of superheated water vapor at 170° C.

[0040] The above-described experiments reveal that humidification by superheated water vapor is superior to humidification by saturated water vapor, which has been considered to be the most efficient humidification, in terms of the amount of water vapor absorbed into air (absolute humidity), water supply utilization, humidifying rate, and energy efficiency, and that humidification by superheated water vapor can achieve the absolute humidity of 11.0 g/m^3, which is considered to be effective to prevent influenza transmission, in a short period of time. Furthermore, with a smaller amount of water vapor, humidification by superheated water vapor can provide substantially the same amount of humidification as that provided by humidification by saturated water vapor; thus, humidification by superheated water vapor is superior to humidification by saturated water vapor in terms of humidifying efficiency, and more energy efficient than humidification by saturated water vapor because of the smaller amount of energy and water consumption required for humidification.

[0041] Because the total hardness of the water obtained from superheated water vapor was below the detection limit (0 ppm), humidification by superheated water vapor can prevent the issue of fine particulate pollution, which is caused by precipitation of impurities in raw water contained in discharged water vapor. Furthermore, because of its excellent water supply utilization, humidification by superheated water vapor can reduce the development of condensed water, prevent the contamination issue caused by bacteria and saprophytes accompanied by the development of condensed water, and destroy spore-bearing bacteria showing high resistance to heat and humidity; thus, humidification by superheated water vapor can prevent infection due directly to discharged water vapor, or due directly to the humidifying unit.

[0042] In this embodiment of the present invention, the highly heating-efficient electrical resistance heater **5** disclosed in Japanese patent No. 3813234 is used in both the saturated-water-vapor-generating step and superheated-water-vapor-generating step. Therefore, the humidifying unit **2** can be compact and provided at low cost. In addition, because development of scales was not confirmed after a long period of use, maintenance work required for the humidifying unit **2** can be reduced.

[0043] Although an embodiment of the present invention has been described above, the present invention is not limited to this embodiment, and various modifications may be made without departing from the spirit and principal concepts of the invention. For example, although the electrical resistance heater **5** disclosed in Japanese Patent No. 3813234 is used for the water-vapor-generating unit **25** for generating saturated water vapor in the embodiment above, conventional water vapor generating units, such as boilers may be used for the water-vapor-generating unit **25**. However, conventional boilers increase construction and operation costs; scales are easily developed in such boilers, thereby decreasing the water-vapor-generating efficiency; and maintenance cost and work are required. Thus, it is preferable to use the electrical resistance heater **5** disclosed in Japanese patent No. 3813234 for the water-vapor-generating unit **25** for generating saturated water vapor. In the embodiment of the present invention, superheated water vapor is supplied to the duct **4**, and the humidified air is sent to the indoor space S by the blower fan **3**; however, superheated water vapor generated in the humidifying unit **2** may be directly supplied to the indoor space S.

[0044] Depending on the circumstances of humidification, humidification by superheated water vapor is not always necessary. The operation of the humidifying unit **2** (water-vapor-generating unit **25** and superheated-water-vapor-generating unit **26**) may be controlled so as to supply saturated water vapor for humidification.

EXPLANATION OF NUMERICAL REFERENCES

[0045] **1** Humidification System
[0046] **2** Humidifying Unit
[0047] **3** Blower Fan
[0048] **4** Duct
[0049] **5** Electrical Resistance Heater
[0050] **20** First Heating Chamber
[0051] **21** Second Heating Chamber
[0052] **25** Water-Vapor-Generating Unit
[0053] **26** Superheated-Water-Vapor-Generating Unit
[0054] **27** Heating Unit

1: A humidifying unit for supplying superheated water vapor of 130° C. or more to air to thereby humidify the air.

2: The humidifying unit according to claim **1** comprising:

a water-vapor-generating unit that is provided in a first heating chamber, the water-vapor-generating unit being configured to heat water supplied to the first heating chamber to thereby generate water vapor;

a superheated-water-vapor-generating unit that is provided in a second heating chamber, the superheated-water-vapor-generating unit being configured to heat the water vapor supplied to the second heating chamber from the water-vapor-generating unit to thereby generate the superheated water vapor.

3: A humidification method comprising supplying superheated water vapor of 130° C. or more to air to thereby humidify the air.

4: A humidification system comprising:

a blower fan for sending air;

a duct for directing the air from the blower fan to an indoor space;

the humidifying unit according to claim **1** for supplying superheated water vapor to the air inside the duct; and

a control unit for controlling the humidifying unit to adjust the temperature and the amount of the superheated water vapor to be supplied to the air inside the duct.

5: The humidification system according to claim **4**, further comprising a heating unit for heating the humidified air inside the duct.

6: The humidification system according to claim **5**, further comprising:

a hygrometer for measuring the humidity of an indoor space; and

a thermometer for measuring the temperature of the indoor space,

wherein the control unit controls the humidifying unit and the heating unit to adjust the temperature, relative humidity, and absolute humidity of the indoor space on the basis of the temperature and humidity of the indoor space measured by the thermometer and hygrometer.

7: A humidification system comprising:

a blower fan for sending air;

a duct for directing the air from the blower fan to an indoor space;

the humidifying unit according to claim **2** for supplying superheated water vapor to the air inside the duct; and

a control unit for controlling the humidifying unit to adjust the temperature and the amount of the superheated water vapor to be supplied to the air inside the duct.

* * * * *