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(54) APPARATUS AND METHOD FOR GENERATING WATER FROM AN AIR STREAM

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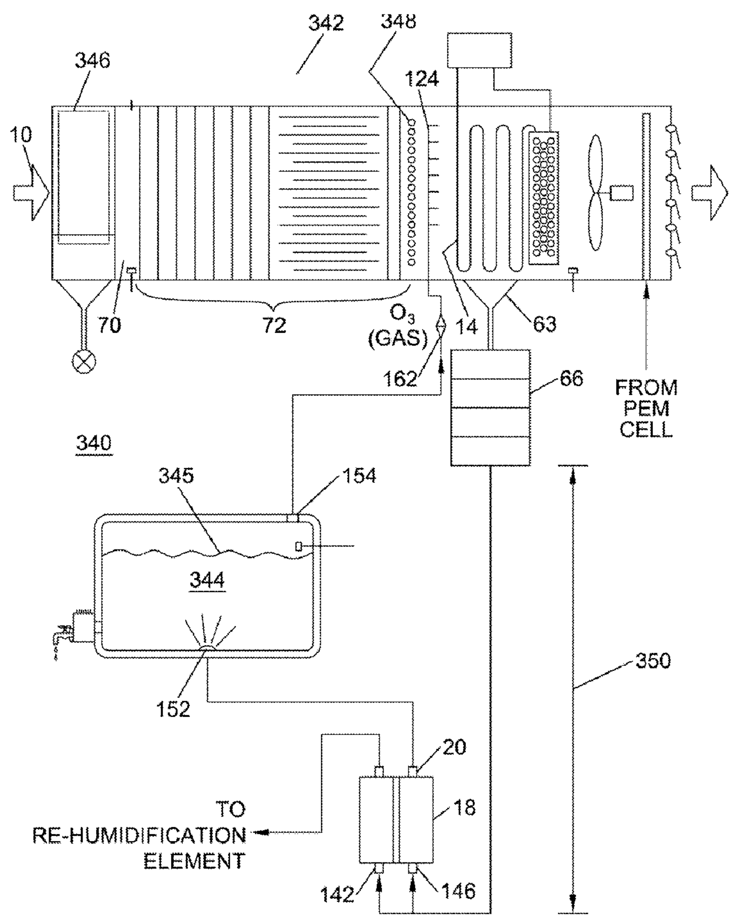
(52) **U.S. Cl.** **62/285**; 62/317

(57) **ABSTRACT**

An apparatus and method for generating water from an air stream is disclosed. The apparatus has an inlet for receiving an air stream, a condensing element located in the air stream, a collector for gathering water vapor condensate that is formed on the condensing element when the condensing element temperature drops below the dew point temperature of the ambient air stream, and an ozone generator that precisely generates ozone required to disinfect the water vapor condensate. In some embodiments of the invention, the ozone is also added to the air stream for disinfecting the air stream and associated elements of the apparatus.



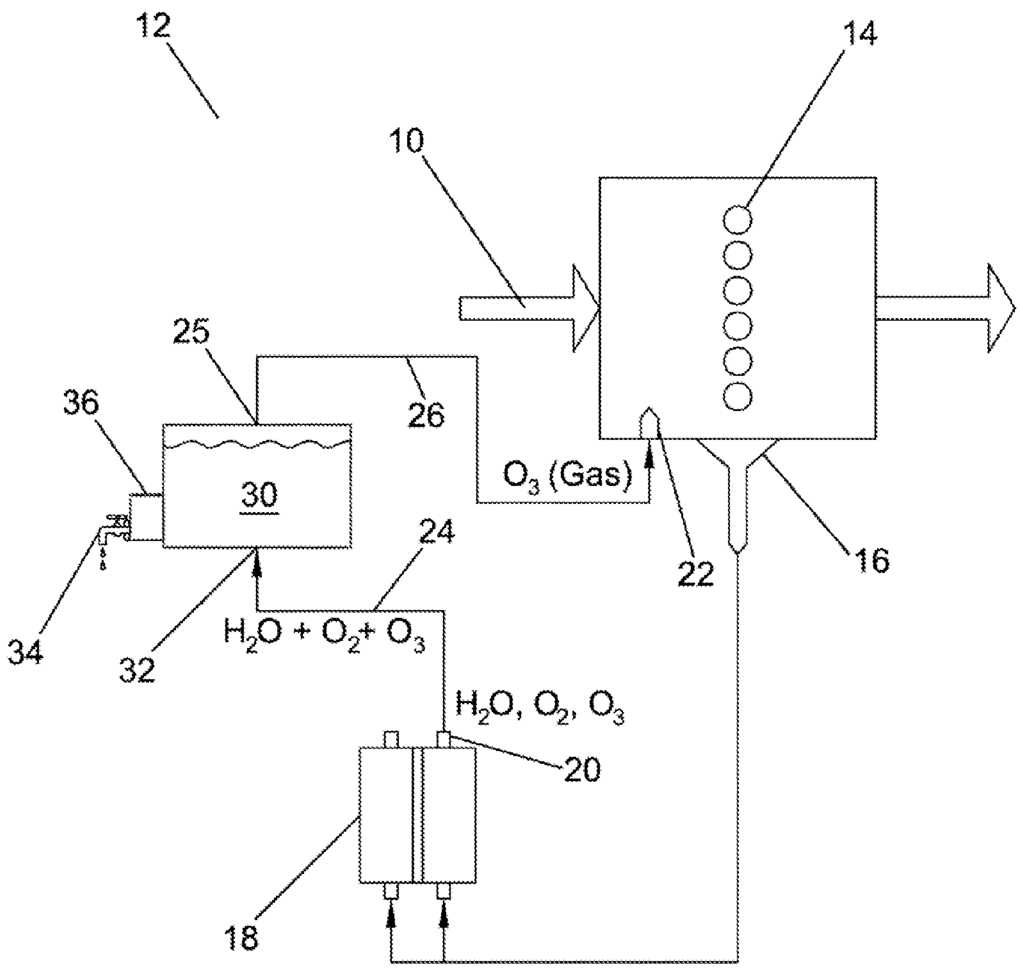


Fig. 1

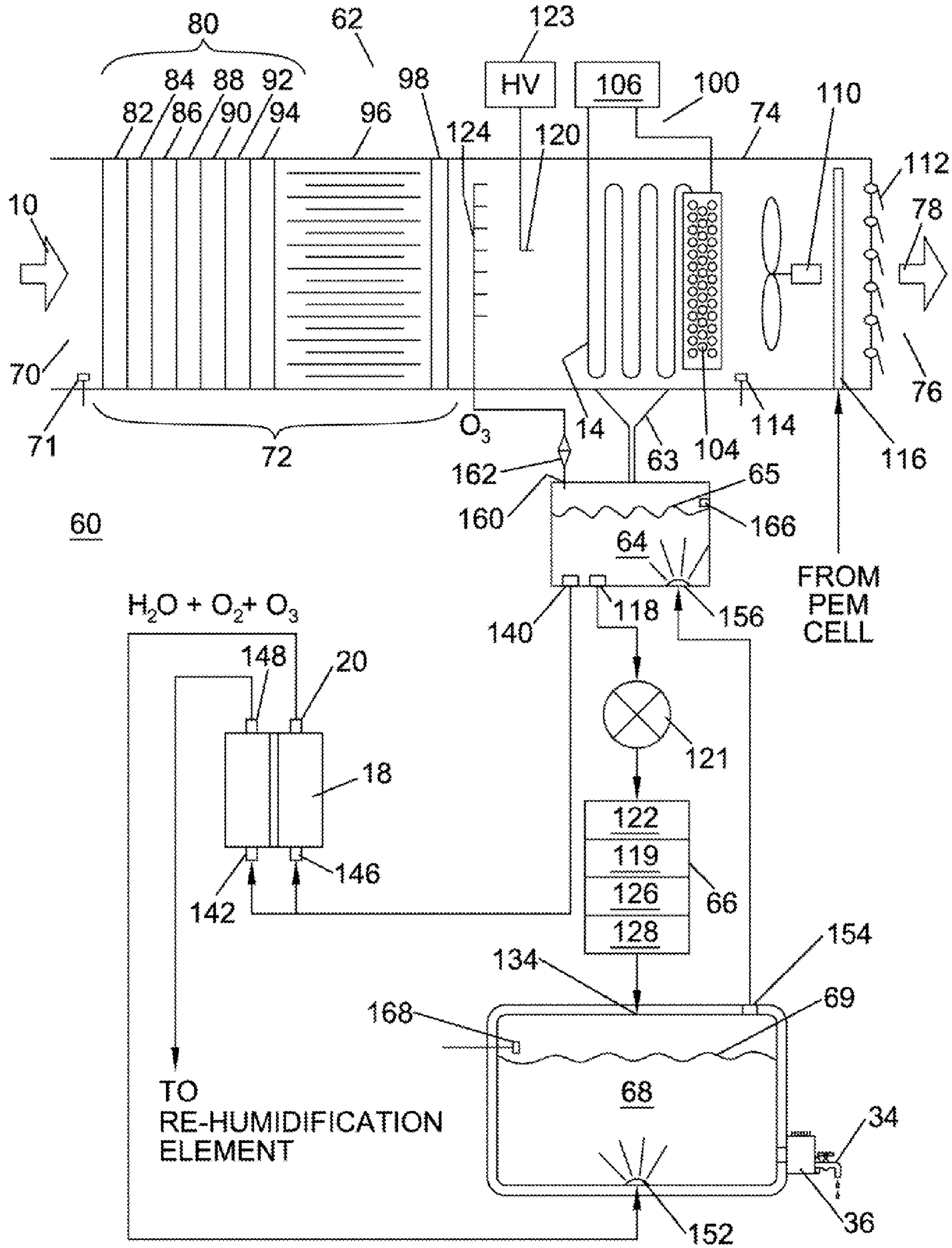

80
62
123
HV
106
100
84 88 92
82 86 90 94
96
98
124
120
74
110
112
78
10
70
71
72
O_3
14
63
104
114
116
76
162
160
65
166
60
64
156
FROM
PEM
CELL
$H_2O + O_2 + O_3$
140
118
148
20
121
18
122
119
126
128
66
142
146
154
134
69
168
TO
RE-HUMIDIFICATION
ELEMENT
68
34
36
152

Fig. 2

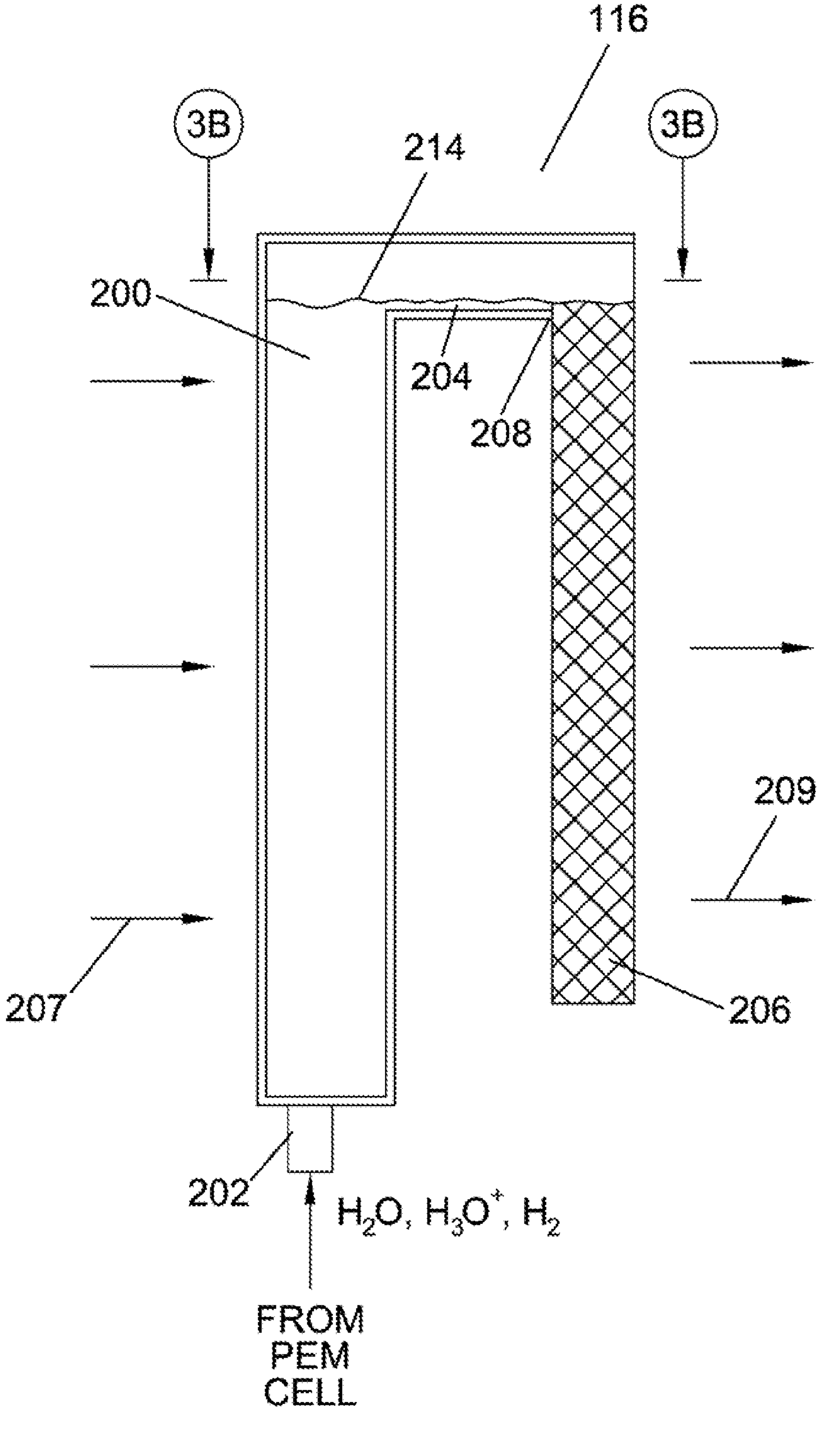

116
3B
3B
214
200
204
208
209
207
206
202
H_2O, H_3O^+, H_2
FROM
PEM
CELL

Fig. 3A

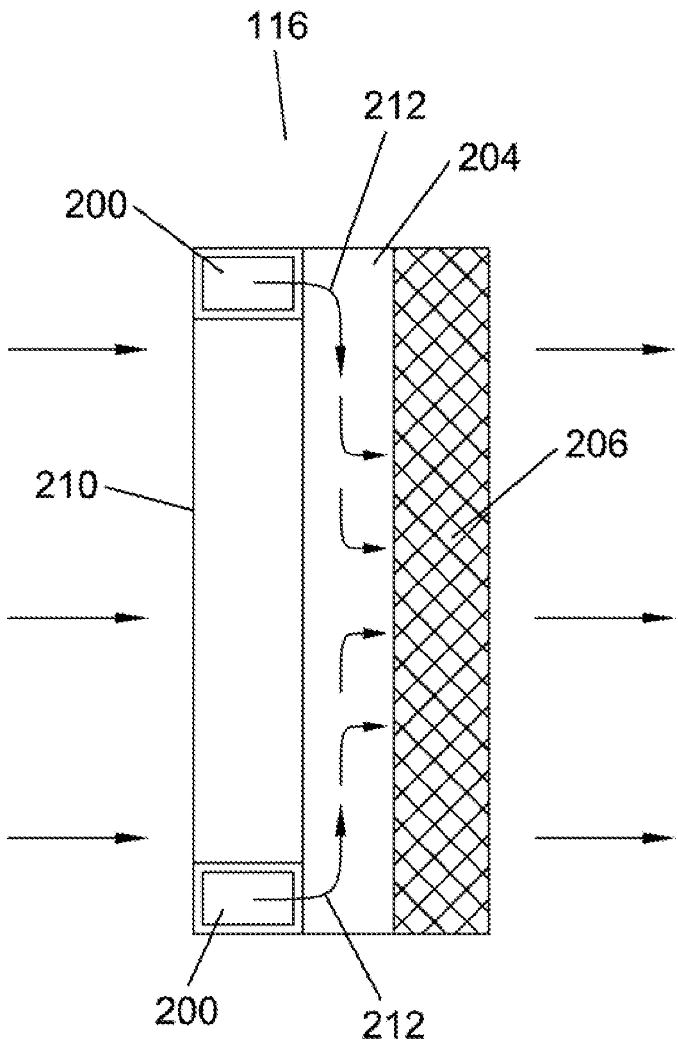


Fig. 3B

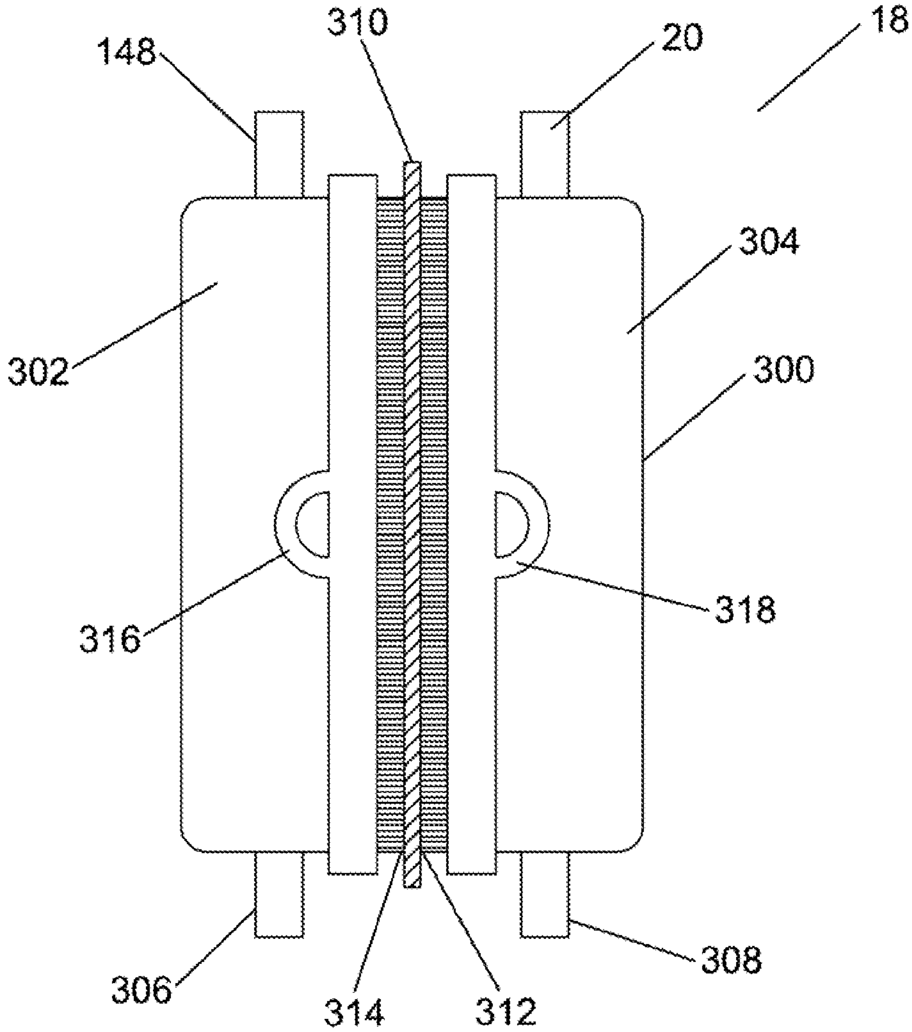


Fig. 4

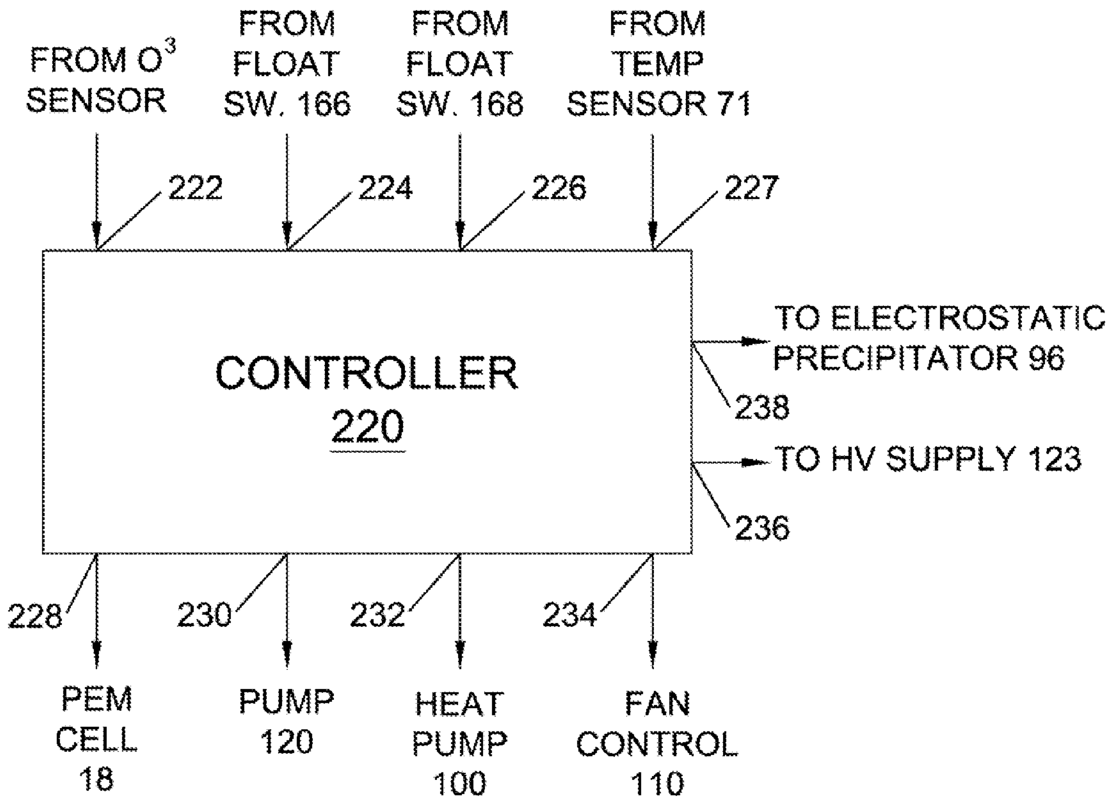

FROM O3 SENSOR
FROM FLOAT SW. 166
FROM FLOAT SW. 168
FROM TEMP SENSOR 71
222
224
226
227
CONTROLLER
220
TO ELECTROSTATIC PRECIPITATOR 96
238
TO HV SUPPLY 123
236
228
230
232
234
PEM CELL 18
PUMP 120
HEAT PUMP 100
FAN CONTROL 110

Fig. 5

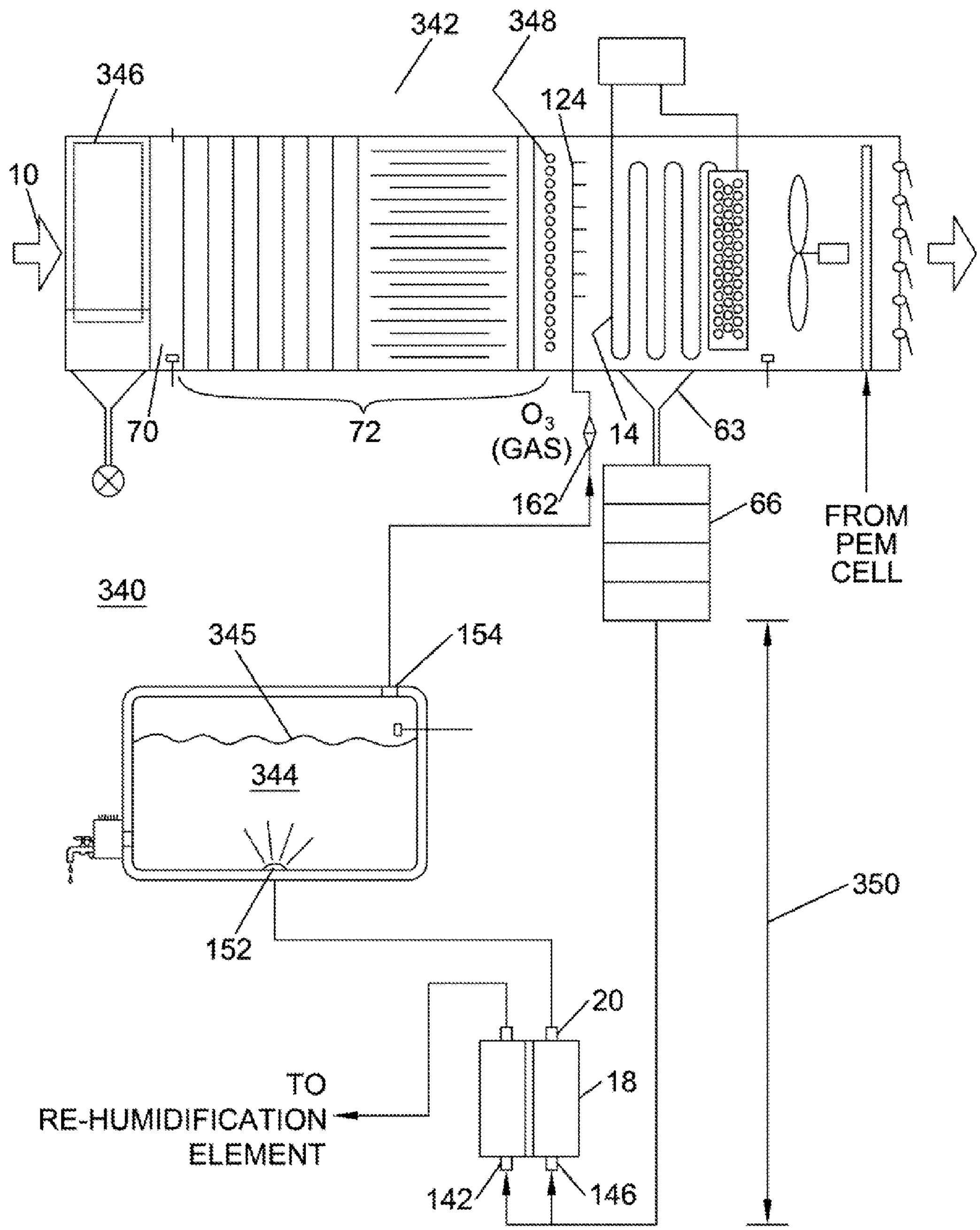

342
348
346
124
10
70
72
O_3
(GAS)
14
63
162
66
FROM
PEM
CELL
340
345
154
344
350
152
20
TO
RE-HUMIDIFICATION
ELEMENT
18
142
146

Fig. 6

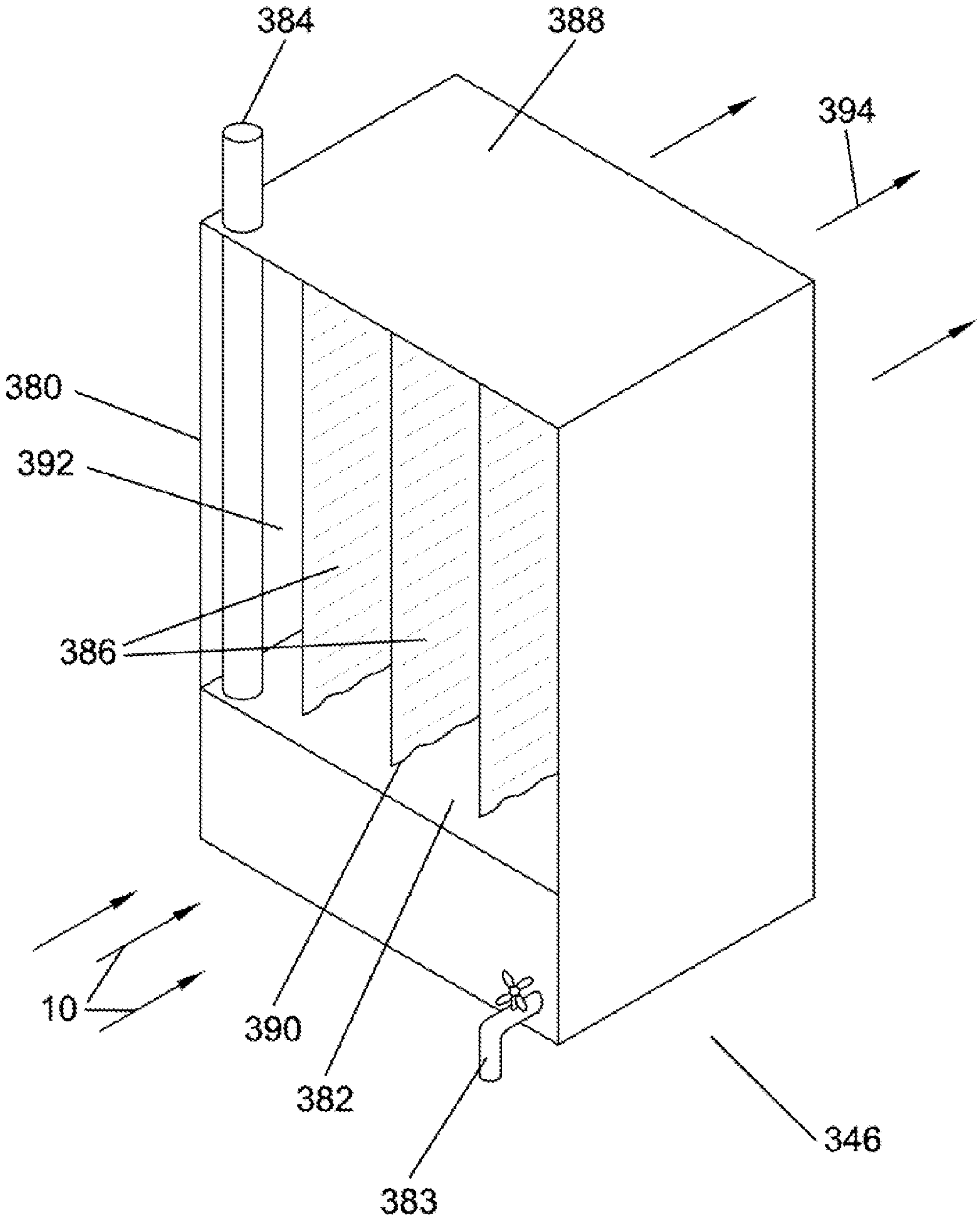


Fig. 7

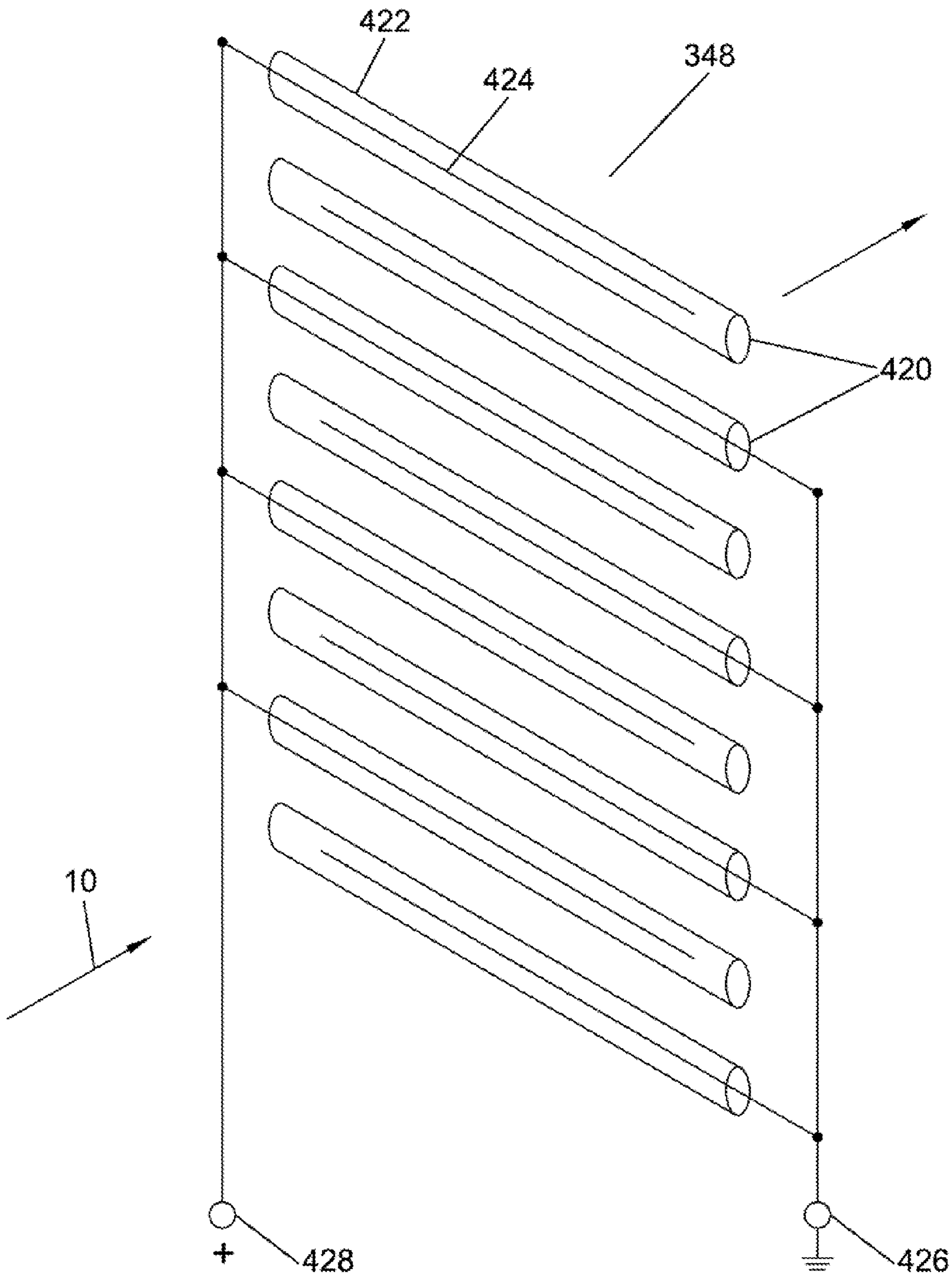


Fig. 8A

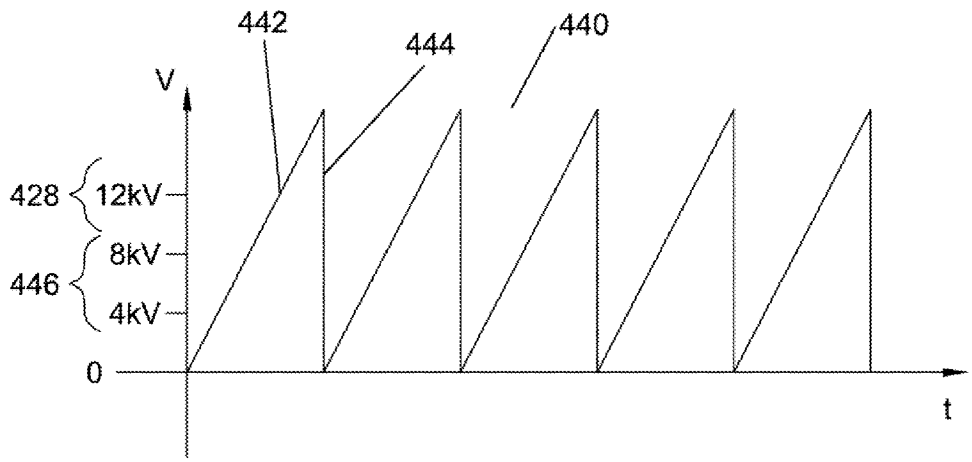


Fig. 8B

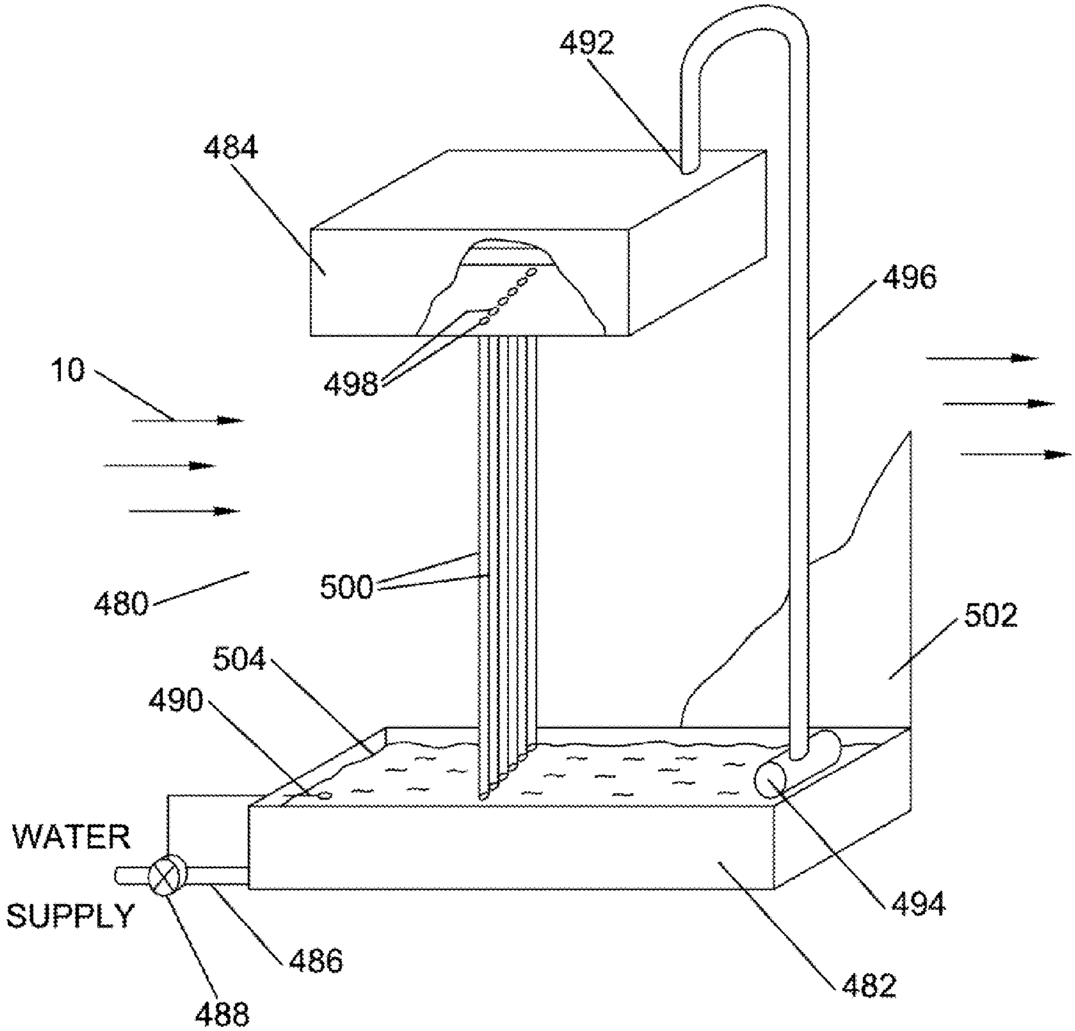

492
484
496
10
498
480
500
502
504
490
WATER
SUPPLY
494
486
482
488

Fig. 9

APPARATUS AND METHOD FOR GENERATING WATER FROM AN AIR STREAM

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of the filing date of U.S. provisional patent application Ser. No. 60/814,884 filed on Jun. 20, 2006.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates generally to generating water from water vapor in ambient air, and more particularly to an apparatus and method for generating water from water vapor in ambient air using an ozone generator for disinfection.

[0004] 2. Description of Related Art

[0005] Water may be generated from ambient air by condensing water vapor. In general, ambient air may contain contaminants, including particulate matter, moulds, spores, mites, volatile organic compounds, and other such contaminants. If these contaminants are not removed from the air or the generated water, the resulting water product that has been generated from ambient air may be contaminated.

[0006] One particular challenge in operating any practical water generation system is to combat the growth of biological contaminants that may not have been removed by filtering or other treatment processes. In particular, some water generation systems suffer from formation of black mould in water reservoirs and tubing.

[0007] In highly developed countries, the quality of drinking water has become of increasing concern to the population, and there is a demand for high quality potable water that is free of contaminants and other impurities.

[0008] In less developed countries, the water supply is often rudimentary or even non-existent and diseases are commonly spread through contaminated drinking water.

[0009] Accordingly, there remains a need for water generation system that generates a potable water product that is substantially free of contaminants.

BRIEF SUMMARY OF THE INVENTION

[0010] In accordance with the present invention, there is provided an apparatus for generating water from an air stream, the apparatus comprising an inlet for receiving an air stream, a condensing element located in the air stream, the condensing element capable of reaching a temperature that is less than or equal to a dew point temperature of the air stream, a collector for gathering water vapor condensate that forms on the condensing element, an ozone generator that uses a portion of the water vapor condensate to generate ozone, and a reservoir for mixing the generated ozone with the water vapor condensate. In some embodiments of the invention, the ozone is also added to the air stream for disinfecting the air stream and associated elements of the apparatus.

[0011] The foregoing paragraph has been provided by way of introduction, and is not intended to limit the scope of the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The invention will be described by reference to the following drawings, in which like numerals refer to like elements, and in which:

[0013] FIG. **1** is a schematic diagram of an apparatus for generating water in accordance with a first embodiment of the present invention;

[0014] FIG. **2** is a schematic diagram of an apparatus for generating water in accordance with a second embodiment of the present invention;

[0015] FIG. **3**A is a side cross-sectional view of a re-humidifier element for use in the apparatus of FIG. **2**;

[0016] FIG. **3**B is a top cross sectional view of the re-humidifier element taken along the line **3**B-**3**B as shown in FIG. **3**A;

[0017] FIG. **4** is a cross sectional view of a PEM cell for use in the apparatus of FIG. **2**;

[0018] FIG. **5** is a functional block diagram of a controller for use with the apparatus shown in FIG. **2**;

[0019] FIG. **6** is a schematic diagram of an apparatus for generating water in accordance with an alternative embodiment of the present invention;

[0020] FIG. **7** is a perspective view of a humidifier element for use in the apparatus of FIG. **6**;

[0021] FIG. **8**A is a perspective view of an ozonation/ionization electrode for use in the apparatus of FIG. **6**;

[0022] FIG. **8**B is a graph of a high voltage waveform for driving the ozonation/ionization electrode shown in FIG. **8**A; and

[0023] FIG. **9** is a partially cut away perspective view of an alternative embodiment of a humidifier element for use in the apparatus of FIG. **6**.

[0024] The present invention will be described in connection with a preferred embodiment, however, it will be understood that there is no intent to limit the invention to the embodiment described. On the contrary, the intent is to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by this specification and the appended claims.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] For a general understanding of the present invention, reference is made to the drawings. In the drawings, like reference numerals have been used throughout to designate identical elements.

[0026] Referring to FIG. **1**, an apparatus **12** for generating water from an air stream is depicted. The apparatus **12** includes a condensing element **14** located in proximity to the air stream **10**. The condensing element may be a refrigeration component that uses the thermodynamic process of compression and expansion of a coolant. Such condensing elements are common in modern day refrigerators, air conditioners, dehumidifiers, and the like. The condensing element **14** is operated such that the condensing element temperature is less than or equal to a dew point temperature of the air stream **10**. This technique causes moisture to be removed from the air stream **10**.

[0027] The apparatus **12** also includes a collector **16** in communication with the condensing element **14**. The collector **16** is configured below the condensing element **14** such that it will collect water vapor condensate from the condensing element **14**. The collector may be made from a plastic, a metal, fiberglass, or another material that would be apparent to those skilled in the art.

[0028] The apparatus **12** further includes a polymer electrolyte membrane (PEM) cell **18**. A polymer electrolyte membrane cell is an electrochemical device, generally termed a fuel cell. The device typically uses hydrogen as fuel in the presence of a platinum catalyst to generate electricity. PEM cells may also be used in reverse from the norm, breaking water into constituent components when electricity is applied to the PEM cell. Such a process may be used in the present invention to generate ozone. In operation, the PEM cell **18** receives at least a portion of the condensate water from the collector **16** generates ozone from the condensate water at a first outlet **20**. A first portion of the generated ozone becomes entrained in the condensate and disinfects the condensate.

[0029] The apparatus **12** may further includes a vent **22**, located in proximity to the air stream **10** and upstream from the condensing element **14**. The vent **22** in operation receives a second portion of the ozone generated in the PEM cell **18**. The ozone mixes with the air stream **10** to treat the air stream and to prevent biological contamination of the apparatus **12**.

[0030] In one embodiment the apparatus **12** also includes a first reservoir **30** having a first opening **32**, located at a low point in the first reservoir. The first opening **32** is in communication with the first outlet **20** of the PEM cell **18** through a water supply line **24** for receiving treated condensate. The treated condensate includes water (H_2O), oxygen (O_2) and ozone (O_3). The first reservoir **30** receives the treated water condensate, which mixes with and treats the condensate in the first reservoir. The outlet **20** of the PEM cell is also in communication with the vent **22**, and a second portion of gaseous ozone from the outlet of the PEM cell, which is not entrained in the condensate, is received at the vent **22** and is operable to treat the air stream **10** and prevent biological growth in the apparatus.

[0031] The first reservoir **30** may further include a spigot **34** for dispensing water from the first reservoir. In some embodiments the first reservoir **30** may also include a heater/cooler element **36**. In some embodiments the element **36** may be configured to cool the condensate in the first reservoir **30**, before dispensing as potable water through the spigot **34**. In other embodiments the element **36** may be configured to heat the condensate or alternatively, a second element **36** may be provided, such that the apparatus **12** is capable of dispensing both cooled and heated condensate.

[0032] Referring now to FIG. **2**, an apparatus for generating water from an ambient air stream **10** in accordance with a second embodiment of the present invention **60** is shown. The apparatus **60** includes a de-humidifier **62**, a collector **63**, a first reservoir **64**, a condensate conditioner **66**, a second reservoir **68**, and a PEM cell **18**.

[0033] The de-humidifier **62** includes an air stream inlet **70** for receiving the air stream **10**, a filtration section **72**, a dehumidification chamber **74**, and an air outlet **76**. The air inlet **70** is in communication with the filtration section **72**, and includes a temperature sensor for producing a signal representing the temperature of the incoming air stream.

[0034] In this embodiment the filtration section **72** includes a plurality of particulate filtration stages **80**. A first filtration stage **82** may include, for example, a polyethylene mesh filter media for removing insects, mites, etc from the incoming air stream **10**. A second filtration stage **84** may include a polycarbonate or polyethylene mesh filter media, which is effective at removing hair, for example. A third filtration stage **86** may include, for example, a 20 um to 50 um polyester spun fiber mesh filter media, which is effective in removing smoke, pollen, dust, and some spores from the air stream. The particulate filtration stage **80** may further include a filtration stage **88**, including, for example, a 1 um-15 um filtration element for removing minute spores and other small airborne contaminants from the incoming air stream. The particulate filtration stage **80** may include further filtration media **90-94**, depending on the contaminants present in the air stream where the apparatus **60** is to be operated. While a plurality of filters are shown, a subset of these or similar types of filters may be used depending on the quality of the air received at the air inlet **70**. In some embodiments of the present invention the filtration section **72** further includes an electrostatic precipitator filter **96**, which imparts a negative charge to airborne particulate matter in the air stream emanating from the filtration stages **80**, causing the particulate matter to become ionized. The electrostatic precipitator filter includes positively charged plates (or ground potential plates (not shown)), to which the ionized particles are attracted, and thus removed from the air stream. The filtration section **72**, in some embodiments of the present invention, further includes a volatile organic compound (VOC) filtration element **98**, which typically includes a carbon impregnated foam filtration media for removing the volatile organic compounds from the incoming air stream **10**.

[0035] The dehumidification chamber **74** includes the condensing element **14** as also shown in FIG. **1**, and further includes a heat pump **100** that cools the condensing element. The heat pump **100** includes a condenser coil **104** and an evaporator coil, which in FIG. **2** is depicted as the condensing element **14**. The evaporator coil and the condenser coil **104** are in communication with a compressor **106**. In operation the heat pump **100** cools the condensing element **14** through evaporation of refrigerant in the heat pump **100**, while the condenser coil **104** is heated. The term "condensing element" is used to refer to an element that may be cooled to facilitate condensation of water vapor thereon.

[0036] In other embodiments of the present invention, the condensing element **14** be cooled by other means, such as, for example, a Peltier cooling device.

[0037] The dehumidification chamber **74** further includes a fan **110** for drawing an air stream into the air inlet **70**, through the filtration section **72**, through the de-humidifier chamber **74**, and discharging the air stream through the air outlet **76**. In the embodiment shown, the air outlet **76** includes a plurality of louvered vanes **112** which are outwardly deflected by the passage of the discharge air stream **78** through the air outlet **76**, and which close under gravitational forces when the fan **110** is deactivated, thus sealing off the air outlet **76**.

[0038] The de-humidifier **62** further includes an ozone sensor **114** located proximate to the air outlet **76** for sensing an ozone level proximate to the air outlet **76** of the de-humidification chamber **74**.

[0039] In this embodiment the de-humidifier **62** further includes an ionization electrode **120**, and a high voltage power supply **123**. The high voltage power supply **123** generates a negative voltage of about 10 kilovolts at the ionization electrode, which functions to generate excess electrons at the ionization electrode **120**. The excess electrons mix with the air stream flowing through the de-humidifier **62**.

[0040] The de-humidifier **62** further includes an ozone vent **124** which is located upstream of the condensing element **14**, and is operable to introduce ozone into the air stream for reducing biological contaminants and inhibiting growth of same in the de-humidification chamber **74**.

[0041] The collector **63** is in communication with the first reservoir **64** and the condensing element **14**, and receives condensed water vapor extracted from the air stream and directs the condensate to the first reservoir **64**. The first reservoir **64** has a first outlet **118**. The apparatus **60** further includes a pump **121**, which is in communication with the first outlet **118** to pump condensate from the first reservoir to the condensate conditioner **66**.

[0042] The condensate conditioner **66** includes a plurality of water conditioning stages. A first water conditioning stage **122** includes a porous ceramic filtration element for removing particulate matter from the condensate received from the pump **121**. A second water conditioning stage **119** includes an activated carbon block filter for removing contaminants such as volatile organic compounds not removed by the volatile organic compound filtration element **98**, from the condensate. A third water conditioning stage **126** may include, in some embodiments of the present invention, re-mineralizing elements such as crushed quartz, granite, anthracite, sand, and the like, which are used to re-mineralize the condensate. A fourth water conditioning stage **128** may include a fiber mesh filter, which inhibits particulates from the re-mineralization element from being introduced into the condensate.

[0043] After being conditioned by the condensate conditioner **66**, the condensate is received at an inlet **134** of the second reservoir **68**. The second reservoir **68** includes the heater/cooler element **36** and the spigot **34** for dispensing heated and/or cooled potable water to a user.

[0044] The first reservoir **64** also includes a second outlet **140** and the PEM cell **18** includes first and second inlets **142** and **146** in communication with the first outlet for receiving a portion of the condensate from the first reservoir **64**. As described above, the PEM cell **18** generates water, oxygen, and ozone at the first outlet **20**. The PEM cell **18** also includes a second outlet **148**, at which the hydrogen (H_2), water, and hydronium ions (H_3O+) are produced. The second outlet **148** of the PEM cell **18** is in communication with the re-humidifier **116** at which water, hydrogen and hydronium are introduced into the air stream.

[0045] Advancing to FIG. **4**, the PEM cell **18** is shown in greater detail. The PEM cell **18** includes a housing **300**, a cathode water cavity **302** and an anode water cavity **304**. The cathode water cavity **302** includes a water inlet **306**, and the anode water cavity **304** includes a water inlet **308**, both water inlets being located at a lower end of the housing **300**. The cathode water cavity **302** and the anode water cavity **304** are separated by an ion-exchange membrane **310**, which acts as a solid electrolyte in the PEM cell **18**. The ion-exchange membrane is contacted by catalysts **312** and **314**. The PEM cell **18** further includes a cathode electrode **316** and an anode electrode **318**. The catalysts **312** and **314** are chosen to enhance the formation of oxygen and ozone at the anode **318** while also inhibiting reformation of ozone molecules into diatomic oxygen.

[0046] The PEM cell **18** further includes a first outlet **20** in communication with the anode water cavity **304** and a second outlet **148** in communication with the cathode water cavity **302**.

[0047] Water is supplied to the PEM cell **18** at the first and second inlets **306** and **308** and flows through the cell to the first and second outlets **20** and **148**. When an external DC excitation current is applied between the anode **318** and the cathode **316**, a portion of the water at the anode is dissociated into oxygen, ozone, and hydrogen ions. Generation of ozone is enhanced by choosing a catalyst **312** for the anode side that causes the anode **318** to have a high overpotential, thus stimulating a more vigorous dissociation of the water.

[0048] The hydrogen ions are able to selectively move through the ion-exchange membrane **310** to the cathode water cavity **302**, where some of the hydrogen ions combine with electrons provided by the external DC current to form hydrogen gas. The remaining hydrogen ions (H+) form hydronium (H3O+), which causes the water leaving the second outlet to be acidic.

[0049] The water leaving the first outlet **20** includes ozone and oxygen entrained in the water. Advantageously, since the ozone is formed directly in the water, a significant portion of the ozone is dissolved in the water leaving the first outlet **20**.

[0050] Ozone is effective in treating water by killing biological contaminants such as bacteria. Furthermore ozone is effective in chemically reacting with contaminants such as iron, arsenic, hydrogen sulfide, nitrites, and complex organics and may also cause some contaminant molecules to agglomerate, thus facilitating filtration. Advantageously, ozone treatment of water does not leave chemical traces in the water (e.g. chlorination), since the ozone dissociates into oxygen over time. However, due to this dissociation over time, a steady state production of ozone is usually desirable for adequate treatment of water.

[0051] The second outlet **148** of the PEM cell **18** is in communication with the re-humidifier **116**. Turning back to FIG. **3**, the re-humidifier **116** is shown in greater detail in side cross-sectional view. Referring to FIG. **3A** the re-humidifier **116** includes a liquid reservoir **200**. The liquid reservoir **200** includes an inlet **202**, which is in communication with the PEM cell **18** (shown in FIG. **2**) for receiving discharge liquid from the PEM cell. The discharge liquid is acidic due to the presence of the hydronium ions, and also includes dissolved hydrogen. The discharge liquid is generally too acidic to be re-combined with the potable treated condensate, and typically requires some form of neutralization.

[0052] To accomplish neutralization, the de-humidifier **62** includes a re-humidifier **116** that has a spillway **204** and a fiber wick **206**. The fiber wick hangs downwardly from an edge **208** of the spillway **204**, and is fabricated from an acid resistant material such as acid resistant polymer. As best shown in top view in FIG. 3B, the liquid reservoir **200** includes an air stream aperture **210**, which facilitates air flow (in the direction shown by arrows **207**) from the de-humidification chamber **74** through the fiber wick **206**.

[**0053**] The re-humidifier **116** operates by receiving the discharge liquid from the PEM cell **18** which causes a level of the liquid in the liquid reservoir **200** to rise to a level **214**, whereupon the liquid flows over the spillway **204** to the fiber wick **206**, in the direction indicated by arrows **212**. The discharge liquid wets the fiber wick **206**, and the airflow **207** causes the liquid to evaporate from the wick **206** into the air stream **209**, which is exhausted through the air outlet (**76** in FIG. **2**). The evaporated hydronium ions quickly dissociate into water and oxygen ions, and the oxygen ions form diatomic oxygen molecules, thereby rendering the hydronium ions benign. The hydrogen is vented into the atmosphere through the outlet **76**, and in low concentrations presents little or no hazard.

[**0054**] Referring to FIG. **2**, advantageously, the hydronium ions are extremely reactive and are effective in further preventing biological contamination in the area of the air outlet **76**. The evaporated water also partially re-humidifies the air stream before being discharged through the outlet **76**.

[**0055**] The second reservoir **68** also includes an ozone inlet **152**, which is in communication with the first outlet **20** of the PEM cell **18** for receiving treated condensate including entrained ozone and oxygen. The second reservoir **68** also includes an outlet **154** which is located at a high point of the second reservoir and which is in communication with an ozone inlet **156**, on the first reservoir **64**, for communicating gaseous ozone from the second reservoir **68** to the first reservoir **64**.

[**0056**] The first reservoir **64** includes an outlet **160** located at a high point in the first reservoir. The outlet **160** is in communication with the ozone vent **124** for introducing ozone into the air stream **10** upstream from the condensing element **14**. In the embodiment shown the apparatus **60** includes a filter **162**. The filter **162** functions to prevent contamination of the first reservoir **64**, in the event of a positive pressure differential occurring between the dehumidification chamber **74** and the first reservoir **64**, which could force air into the reservoir.

[**0057**] The first reservoir **64** may further include a first float switch **166** for generating a signal when a level of the condensate in the first reservoir reaches a pre-determined level. The second reservoir **68** also may include a second float switch **168** for generating a signal when the condensate level in the second reservoir reaches a pre-determined level.

[**0058**] Referring now to FIG. **5**, in one embodiment the apparatus **60** further includes a controller **220**. The controller **220** monitors and adjusts various processes of the apparatus **60**. The controller **220** includes a first input **222** for receiving a signal representing a concentration of ozone from the ozone sensor **114**. The controller **220** also includes a second input **224** for receiving the signal from the first float switch **166**, and an input **226** for receiving the signal from the second float switch **168**. The controller **220** further includes an input **227** for receiving a temperature signal from the inlet air temperature sensor **71**.

[**0059**] The controller **220** also includes an output **228** for producing a signal for controlling an excitation current to the PEM cell **18**. The controller **220** further includes an output **230** for producing a signal for controlling the pump **121**, an output **232** for producing a signal for controlling the heat pump **100**, and an output **234** for producing a signal for controlling the operation of the fan **110**. The controller **220** may include further outputs for activating and de-activating the high voltage supply **123**, which drives the ionization electrode **120**, and/or the electrostatic precipitator filter **96**.

[**0060**] For a complete understanding of the present invention, the operation of the apparatus **60** is described with reference to FIG. **2**, FIG. **3**, and FIG. **4**. Referring to FIG. **2**, the fan **110** operates to draw the air stream **10** through the filtration section **72** and the dehumidification chamber **74**, and to discharge the air stream **78** through the air outlet **76**. The incoming air stream **10** is received at the air inlet **70** and passes through the filtration section **72** into the de-humidifier chamber **74**. The filtration section **72** removes most particulate matter, mould, spores, dust, mites, smoke particles, and volatile organic compounds from the incoming air stream **10**.

[**0061**] The ozone vent **124** introduces ozone into the dehumidification chamber **74** ahead of the condensing element **14**. The ozone is effective in killing biological contaminants, which are not removed by the filtration section **72**. The ozone also prevents growth of biological contaminants in the condensing element **14**, the condenser coils **104**, and the dehumidification chamber **74**.

[**0062**] Since ozone, above a certain concentration, is considered to be harmful to humans, in one embodiment the ozone concentration may be monitored and controlled by monitoring the signal produced by the ozone sensor **114**. Referring to FIG. **5** the ozone concentration signal is received from the ozone sensor **114** at the input **222** of the controller **220**. The controller produces the PEM cell control signal at the output **228** in response to the ozone concentration. When the ozone concentration in the outlet discharge air stream **78** increases above a threshold level, the controller reduces the drive current to the PEM cell, thus reducing the generation of ozone at the PEM cell. In this manner, the concentration of ozone vented into the atmosphere though the air outlet **76** may be limited to a safe level.

[**0063**] When the heat pump **100** is activated by the controller **220** the condensing element **14** is cooled to a temperature at or below the dew point of the incoming air stream **10**, as indicated by the temperature sensor **71**. Water vapor in the air stream **10** condenses onto the condensing element **14**, and drips into the collector **63**. The collector **63** directs the water vapor condensate into the first reservoir **64** and the condensate accumulates in the first reservoir until the level of the water activates the first float switch **166**. The controller **220** (shown in FIG. **5**) receives the signal from the first float switch **166** at the inlet **224** and produces an activation signal at the output **230** to activate the pump **121** and cause condensate to be pumped from the first reservoir **64** through the condensate conditioner **66**, and into the second reservoir **68**.

[**0064**] The condensate conditioner **66** filters the condensate to remove various contaminants as described above, and also may re-mineralize the condensate to improve the taste of the water supplied by the apparatus **60**.

[0065] The condensate is accumulated in the second reservoir **68** until the level of the condensate in the reservoir activates the second float switch **168** such that the controller **220** (shown in FIG. **5**) receives a signal at the input **226** indicating that the condensate level in the second reservoir has reached the level of the second float switch **168**. In response the controller produces a signal at the output **234** to deactivate the fan and a signal at the output **232** to deactivate the heat pump, thus discontinuing generation of condensate while the second reservoir is full. The controller may further produce output signals at the outputs **236** and **238** to de-activate the HV ionization supply **123**, and the electrostatic precipitator filter **96** respectively. The controller **220** is further configured to produce signals at the outputs **232** and **234** to activate the heat pump **100** and fan **110** when the condensate level in the second reservoir **68** falls sufficiently to de-activate the second float switch **168**.

[0066] The heater/cooler element **36** cools and/or heats the collected condensate, which may be dispensed as treated potable drinking water through the spigot **34**.

[0067] A portion of the condensate in the first reservoir **64** is diverted through the second outlet **140** to the first and second inlets **142** and **146** of the PEM cell **18**. As described previously the PEM cell **18** generates water, oxygen and ozone at the first outlet **20**. The water, oxygen and ozone are received at the ozone inlet **152** in the second container **68** and bubbles through the second container causing the condensate to re-circulate while simultaneously being treated by the ozone. The ozone in the second reservoir **68** treats the condensate accumulated therein preventing biological growth, and contamination of the condensate in the second reservoir. Advantageously the oxygen entrained in the condensate at the first outlet **20** of the PEM cell **18** oxygenates the condensate in the second reservoir **68**, which further enhances the taste of the water generated by the apparatus **60**.

[0068] A portion of the ozone in the second reservoir **68** diffuses as gaseous ozone from a surface **69** of the condensate accumulated in the second reservoir, and is communicated through the outlet **154** to the ozone inlet **156** of the first reservoir **64**.

[0069] The gaseous ozone received at the first reservoir **64** from the second reservoir mixes and becomes entrained in the condensate accumulated in the first reservoir **64**, thus treating the condensate in the first reservoir. A portion of the ozone also diffuses from the surface **65** of the condensate in the first reservoir **64** and is communicated through the outlet **160**, through the filter **162**, to the ozone vent **124**.

[0070] The re-humidifier **116** receives the discharge liquid from the second outlet **148** of the PEM cell **18**, and causes the hydronium ions in the water to be evaporated and dissociated as described above.

[0071] In one embodiment where the apparatus **60** includes the ionization electrode **120** and high voltage power supply **123**, electrons are generated at the electrode and introduced into the air stream ahead of the condensing element **14**. The electrons are operable to generate anions of oxygen in the air stream and at least a portion of the anions dissolve into the water vapor condensate which collects on the condensing element **14**. It is believed that the oxygen anions are effective in enhancing oxygen retention in the water, thus producing a potable water product which has a high proportion of entrained oxygen.

[0072] Referring to FIG. **6**, an apparatus **340** for generating water from an ambient air stream **10** in accordance with an alternative embodiment of the present invention is shown. The apparatus **340** includes several elements in common with the apparatus **60** shown in FIG. **2**, and accordingly similar elements are numbered using similar reference numerals as in FIG. **2**.

[0073] Referring to FIG. **6**, the apparatus **340** includes a de-humidifier **342**, and a reservoir **344** and the collector **63**, the condensate conditioner **66**, and the PEM cell **18** shown in FIG. **2**.

[0074] In the embodiment depicted, the de-humidifier **342** includes a humidifier element **346**, which is located ahead of the air inlet **70**. The humidifier element **346** is shown in greater detail in FIG. **7**. Referring to FIG. **7**, the humidifier element **346** includes a housing **380**, which includes a water reservoir **382** at a lower portion thereof. The humidifier element **346** further includes a water inlet **384** which is in communication with the reservoir **382** for receiving untreated (and possibly contaminated) water. The humidifier element **346** further includes a plurality of polyfiber panels **386**, which are suspended from a top portion **388** of the housing **380**. A lower end **390** of each of the polyfiber panels **386** is at least partially immersed in the water accumulated in the reservoir **382**. The humidifier element **346** further includes an airflow aperture **392** for receiving the air stream **10**.

[0075] The humidifier element **346** generally operates by receiving, at the inlet **384**, water which has not been treated, and pre-humidifies the incoming air stream **10** to enhance the water vapor content thereof. For example, the water may be from a ground water supply, a river, a stream, or any other untreated source of water.

[0076] The untreated water is accumulated in the reservoir **382** and sediment and other heavier particulate matter is permitted to settle in the reservoir. This matter may be removed from the reservoir through the drain **383**. The water in the reservoir **382** wicks up and along the polyfiber panels **386** by capillary attraction, and is evaporated into the air stream **10** flowing between the polyfiber panels. The air stream **394** leaving the humidifier element **346** generally has enhanced water vapor content due to the additional water vapor evaporated from the polyfiber panels **386**.

[0077] Advantageously the humidifier element **346** facilitates use of the apparatus **340** in environments where the air stream **10** has relatively low water vapor content.

[0078] Referring back to FIG. **6**, in this embodiment the de-humidifier **342** further includes an ozonator/ionizer **348**. The ozonator/ionizer **348** is shown in greater detail in FIG. **8**. Referring to FIG. **8**A the ozonator/ionizer **348** includes a plurality of electrode members **420**, each electrode member including a conductive electrode **424**, which is surrounded by a glass enclosure **422**. Alternating, electrode members **420** are connected to a ground terminal **426** and a high voltage excitation signal terminal **428** respectively. The excitation is provided by a high voltage signal generator (not shown) which is configured to produce a waveform **440** as shown in FIG. **8**B.

[0079] Referring to FIG. 8B the waveform **440** generally has the form of a saw-tooth function and includes a rising edge **442** and a falling edge **444**. The rising edge **442** includes a first portion **446**, including voltages up to about 10 kV. The rising edge **442** of the waveform **440** further includes a second portion **448**, including voltages from about 10 kV up to about 12 kV. In one embodiment, the frequency of the saw-tooth waveform may be between 1 kHz and 7 kHz.

[0080] When the voltage is below about 10 kV, the ozonator/ionizer **348** produces a low concentration of ozone and a high concentration of free electrons. As the voltage increases above about 10 kV a corona discharge begins to form between the electrode members **420**, and the ozonator/ionizer **348** produces a higher concentration of ozone and a lower concentration of free electrons. At a voltage of approximately 12 kV the ozonator/ionizer produces predominantly ozone, and the corona discharge may begin to arc across the electrode member **420**, thus short circuiting the high voltage signal generator whereupon the voltage returns to 0V along the falling edge **444**.

[0081] The glass enclosure **422** surrounding each electrode prevents corrosion of the conductive electrodes **424** and also provides an easily cleanable surface. Referring back to FIG. **6**, the ozonator/ionizer **348** enhances the production of ozone in the de-humidifier **342**, which supplements the introduction of ozone introduced through the ozone vent **124**. The ozonator/ionizer **348** generates both free electrons and ozone, and may be used in co-operation with, or instead of the ozone vent **124** and/or the ionization electrode **120** (shown in FIG. **2**).

[0082] Still referring to FIG. **6**, in this embodiment the first and second inlets **142** and **146** of the PEM cell **18** are directly in communication with the condensate conditioner **66**. The first and second inlets **142** and **146** of the PEM cell **18** are located at a sufficient vertical distance indicated by the arrow **350** from the collector **63**, such that the apparatus **340** is capable of operating by gravity feed alone. In one embodiment the vertical distance **350** is about 30 inches. The first outlet **20** of the PEM cell **18** is in communication with the ozone inlet **152** of the reservoir **344**. The outlet **154** of the reservoir **344** is communication with the ozone vent **124** via the filter **162**.

[0083] The operation of the apparatus **340** is described with reference to FIG. **6**, FIG. **7**, and FIG. **8**. The air stream **10** is received at the humidifier **346**, which humidifies the air stream **10**, prior to passing through the filtration elements **72**. The ozonator/ionizer **348** generates free electrons and ozone in the air stream **10** with the additional ozone generation supplementing the ozone introduced through the ozone vent **124**. The water vapor in the air stream condenses on the condensing element **14**, and is collected by the collector **63**. The collector **63** directs the condensate through the condensate conditioner **66**, which performs the same functions as described above in reference to FIG. **2**.

[0084] In this embodiment, all of the condensate collected by the collector **63** is passed through the condensate conditioner **66** and through the PEM cell **18**. Furthermore in this embodiment the flow is achieved through gravitational forces alone, thus eliminating the need for a pump and associated controller.

[0085] Ozone and oxygen are generated in the condensate at the first outlet **20** of the PEM cell **18**, and communicated to the ozone inlet **152** in the reservoir **344**, thus treating the condensate accumulated in the reservoir. A portion of the ozone in the condensate accumulated in the reservoir **344** diffuses to the surface **345** and collects above the surface, where it is communicated through the outlet **154**, through the filter **162**, and to the ozone vent **124**, where it treats the air stream and inhibits growth of biological contaminants in the de-humidifier **342**.

[0086] Referring lastly to FIG. **9**, an alternative embodiment of the humidifier element **480** is depicted. The humidifier element **480** includes a first water container **482** and a second water container **484**. The second container **484** is located above the first container **482**.

[0087] The first container **482** includes an inlet **486** for receiving untreated water, from for example a municipal water supply or a ground water supply. The inlet **486** includes a valve **488** for controlling the supply of water to the first container, and further includes a float switch, which is in communication with the valve **488** for controlling the supply of water to the first container. The first container **482** further includes a pump **494**, which is in communication with an outlet tube **496**.

[0088] The second container **484** includes an inlet **492**, which is in communication with the outlet tube **496** for receiving water from the first container. In the embodiment shown, the pump **494** includes a float switch (not shown) for activating the pump when the water in the first container is at a sufficient level to feed the pump.

[0089] The second container **484** further includes a plurality of outlets **498** for generating a plurality of water streams **500** between the second container and the first container **482**. The humidifier **480** is located in a duct section **502** (only a portion shown), which is configured to receive the air stream **10** and direct the air stream through the plurality of streams **500**.

[0090] In operation, the humidifier **480** receives water at the inlet **486** and the second container **484** is filled until a water level **504** activates the float switch **490**, thus causing the valve **488** to interrupt the flow of water. The float switch activated pump **494** operates whenever there is sufficient water in the first container **482**, and causes water to be pumped from the first container, through the outlet tube **496**, and into the second container **484** through the inlet **492**.

[0091] The water pumped into the second container **484** flows downwardly through the plurality of outlets **498**, forming the plurality of streams **500** which return to the first container **482**. The air stream **10** flows through the plurality of streams **500**, as water in the streams is evaporated, thus humidifying the air stream **10**.

[0092] Advantageously, embodiments of the present invention described above provide for the generation of ozone from the condensate, which is subsequently entrained in the condensate and operable to treat the condensate, thus prevention biological contamination thereof. Diffused ozone gas, collected from the treated condensate, is re-used to treat the air stream components, thus preventing biological contamination thereof. The use of a PEM cell facilitates production of sufficient quantities of ozone and provides oxygen for oxygenating the condensate. If desired, additional ozone may be generated in the air stream, along with the generation of ionizing electrons as described above.

[0093] While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.

[0094] It is therefore, apparent that there has been provided, in accordance with the various objects of the present invention, an apparatus for generating water from an ambient air stream. While the various objects of this invention have been described in conjunction with preferred embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of this specification and the appended claims.

What is claimed is:

1. An apparatus for generating water from an air stream, the apparatus comprising:

An inlet for receiving an air stream;

a condensing element located in the air stream, the condensing element capable of reaching a temperature that is less than or equal to a dew point temperature of the air stream;

a collector for gathering water vapor condensate that is formed on the condensing element;

an ozone generator that uses a portion of the water vapor condensate to generate ozone; and

a first reservoir for mixing the generated ozone with the water vapor condensate.

2. The apparatus as recited in claim 1, wherein the ozone generator is a fuel cell.

3. The apparatus as recited in claim 2, wherein the fuel cell is a polymer electrolyte membrane.

4. The apparatus as recited in claim 1, further comprising a connection between the ozone generator and the inlet for receiving an air stream.

5. The apparatus as recited in claim 1, further comprising a second reservoir for storing water vapor condensate, the second reservoir operatively coupled to the collector.

6. The apparatus as recited in claim 5, further comprising a connection between the first reservoir containing ozone enhanced water vapor condensate and the second reservoir containing water vapor condensate.

7. The apparatus as recited in claim 6, wherein the connection is modulated by a controller that dynamically adjusts the ratio of ozone enhanced water vapor condensate from the first reservoir to the water vapor condensate from the second reservoir.

8. The apparatus as recited in claim 1, further comprising a re-mineralization device for adding minerals to the water vapor condensate.

9. An apparatus for generating water from an air stream, the apparatus comprising:

An inlet for receiving an air stream;

a condensing element located in the air stream, the condensing element capable of reaching a temperature that is less than or equal to a dew point temperature of the air stream;

a collector for gathering water vapor condensate that is formed on the condensing element;

an ozone generator that uses a portion of the air stream to generate ozone; and

a first reservoir for mixing the generated ozone with the water vapor condensate.

10. The apparatus as recited in claim 9, wherein the ozone generator is a high voltage discharge device.

11. The apparatus as recited in claim 9, further comprising a connection between the ozone generator and the inlet for receiving an air stream.

12. The apparatus as recited in claim 9, further comprising a second reservoir for storing water vapor condensate, the second reservoir operatively coupled to the collector.

13. The apparatus as recited in claim 12, further comprising a connection between the first reservoir containing ozone enhanced water vapor condensate and the second reservoir containing water vapor condensate.

14. The apparatus as recited in claim 13, wherein the connection is modulated by a controller that dynamically adjusts the ratio of ozone enhanced water vapor condensate from the first reservoir to the water vapor condensate from the second reservoir.

15. The apparatus as recited in claim 9, further comprising a re-mineralization device for adding minerals to the water vapor condensate.

16. A method for generating water from an air stream, the method comprising:

cooling a condensing element to a temperature that is below the dew point of an air stream;

receiving the air stream at the condensing element;

collecting vapor condensate from the condensing element;

directing a portion of the water vapor condensate through a ozone generator for generating ozone; and

mixing the ozone with the water vapor condensate to produce disinfected water.

17. The method as recited in claim 16, wherein the ozone generator is a polymer electrolyte membrane.

18. The method as recited in claim 16, wherein the ozone generator is a high voltage discharge device.

19. The method as recited in claim 16, further including the step of adding minerals to the disinfected drinking water.

20. The method as recited in claim 16, further including the step of directing a portion of the generated ozone into the air stream.

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