US 20070119699A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2007/0119699 A1
Chambers et al. (43) Pub. Date: May 31, 2007

(54) APPARATUS AND METHOD FOR SANITIZING AIR AND SPACES

(75) Inventors: **William R. Chambers**, Vienna, VA (US); **Carlos Antonio Lima**, Santiago (CL); **Robert D. McDonald**, Great Falls, VA (US); **Terrance O. Woodbridge**, Cary, NC (US)

Correspondence Address:
MCGINN INTELLECTUAL PROPERTY LAW GROUP, PLLC
8321 OLD COURTHOUSE ROAD
SUITE 200
VIENNA, VA 22182-3817 (US)

(73) Assignee: **AirOCare, Inc.**, Rockville, MD

(21) Appl. No.: **11/289,363**

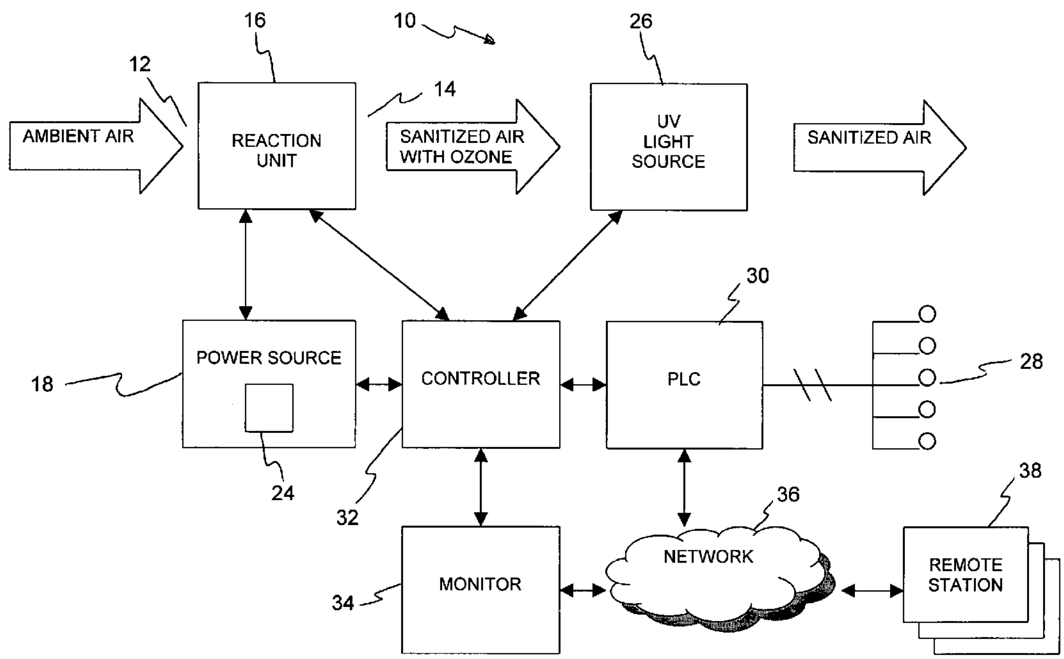
(22) Filed: **Nov. 30, 2005**

Publication Classification

(51) Int. Cl.
A61L 2/04 (2006.01)
B01J 19/08 (2006.01)
(52) U.S. Cl. **204/176**; 422/186.07

(57) **ABSTRACT**

An apparatus for sanitizing air including a reaction unit for generating reactive oxygen species from oxygen in the air received in the reaction unit to be sanitized, wherein air-borne contaminants in the air to be sanitized are neutralized by the generated concentration of reactive oxygen species before the air is discharged from the reaction unit. The reaction unit may further generate ozone from the oxygen in the air and the generated ozone is discharged with the air from the reaction unit to sanitize surfaces in the environment into which the sanitized air is discharged.



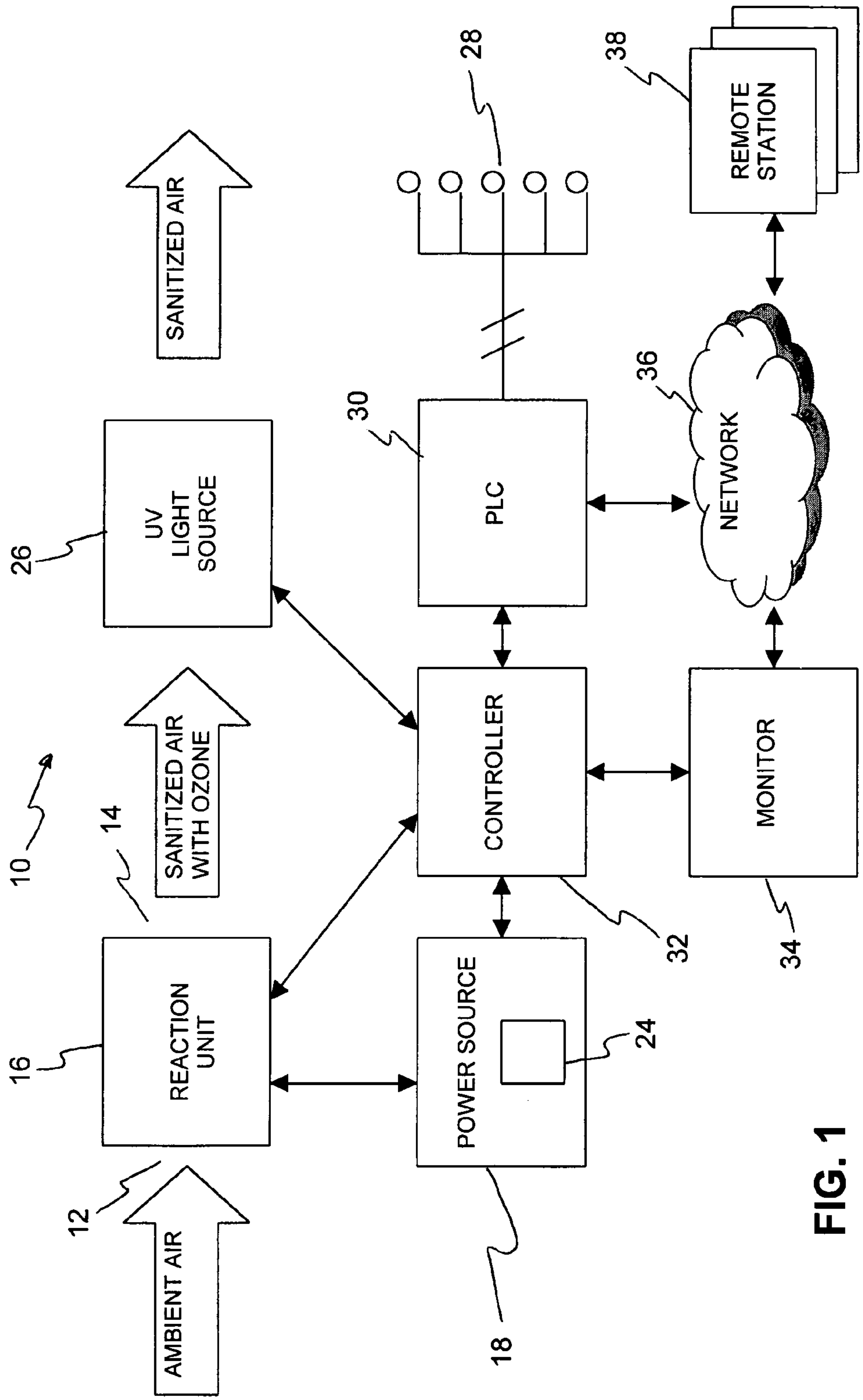

10
AMBIENT AIR
12
REACTION UNIT
16
14
SANITIZED AIR WITH OZONE
UV LIGHT SOURCE
26
SANITIZED AIR
POWER SOURCE
24
18
CONTROLLER
32
PLC
30
28
MONITOR
34
NETWORK
36
REMOTE STATION
38

FIG. 1

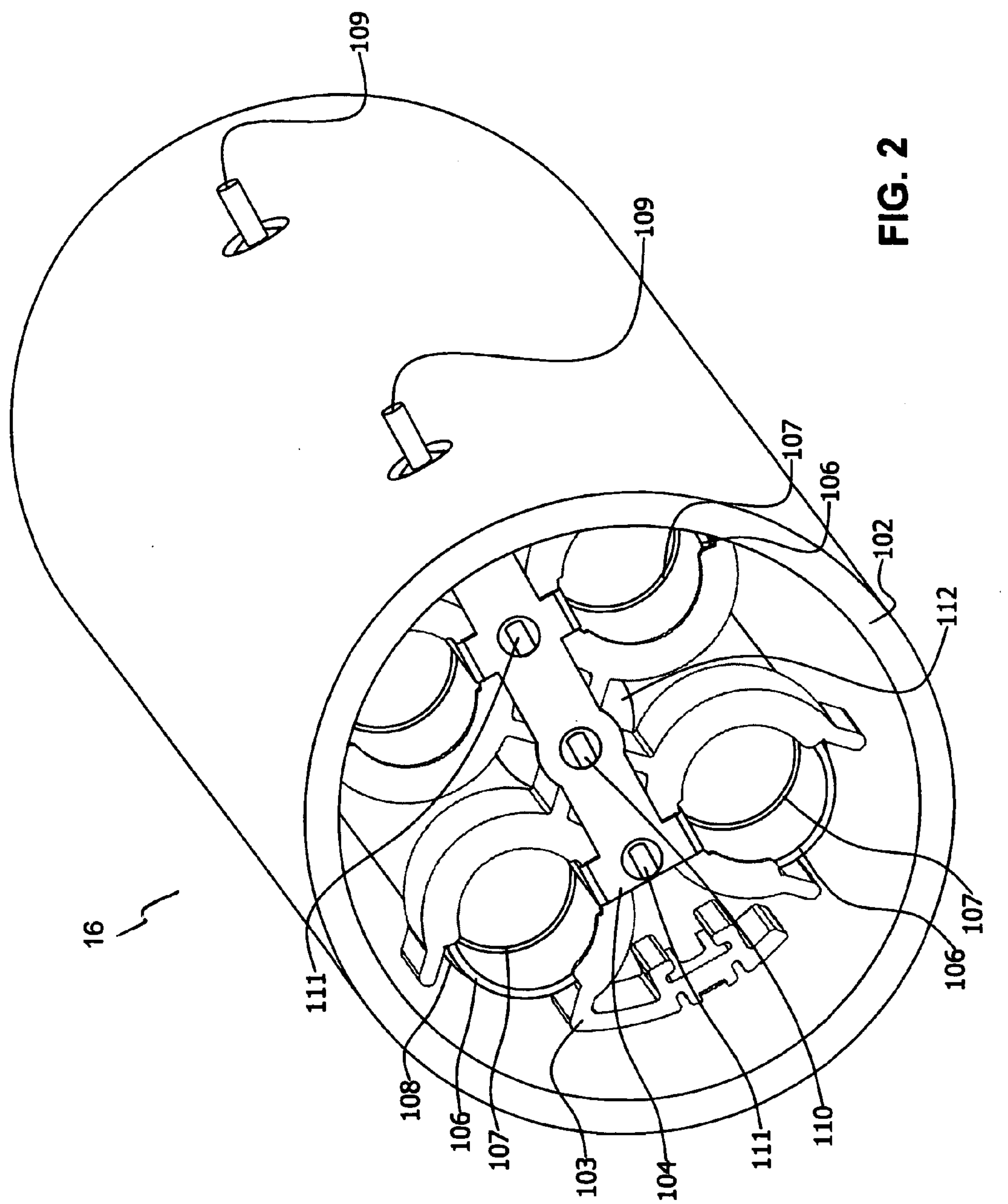

109
109
107
106
102
112
107
106
16
111
108
106
107
103
104
111
110

FIG. 2

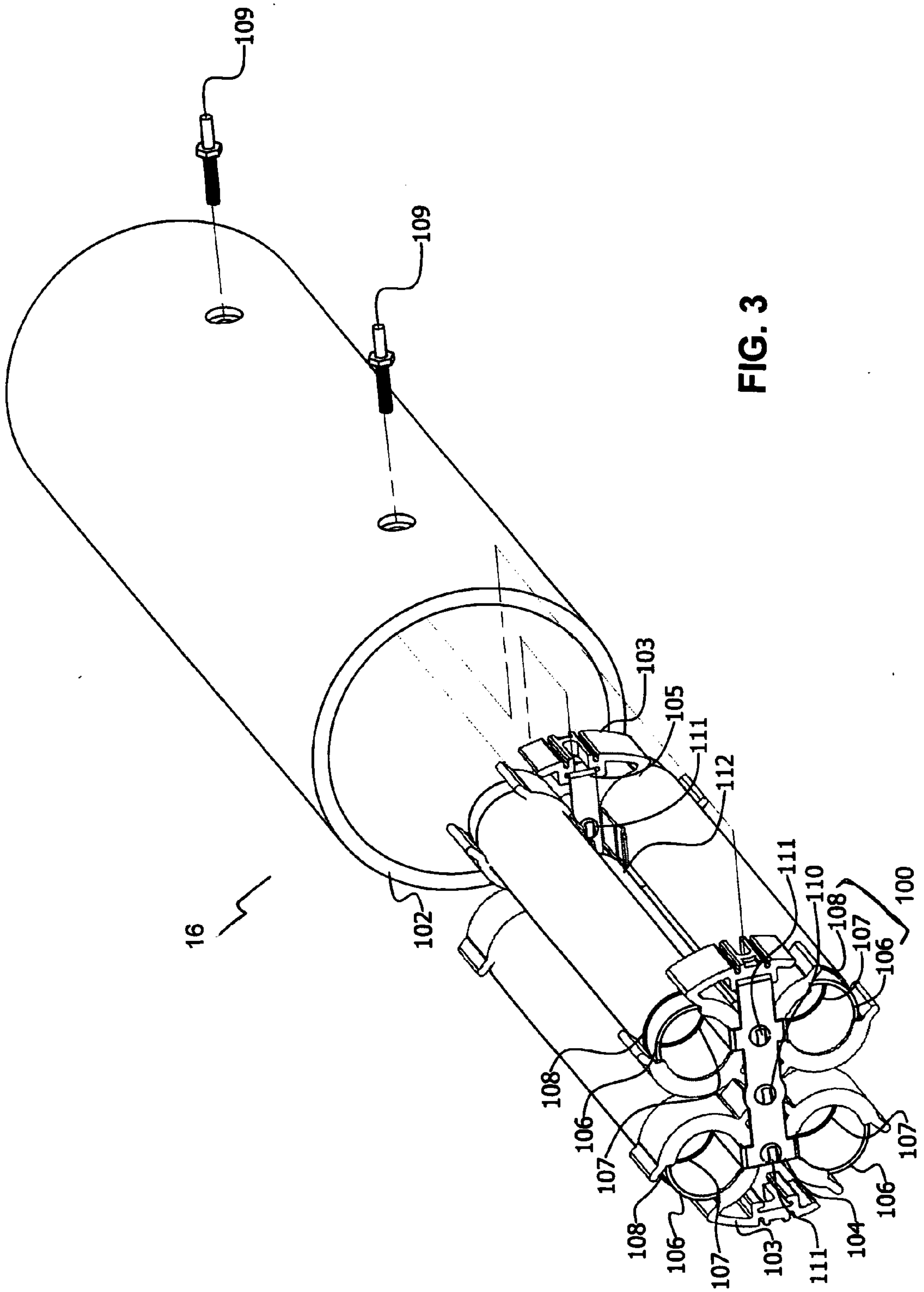

109
109
103
105
111
112
111
110
108
107
106
100
16
102
108
106
107
107
106
108
106
107
103
111
104

FIG. 3

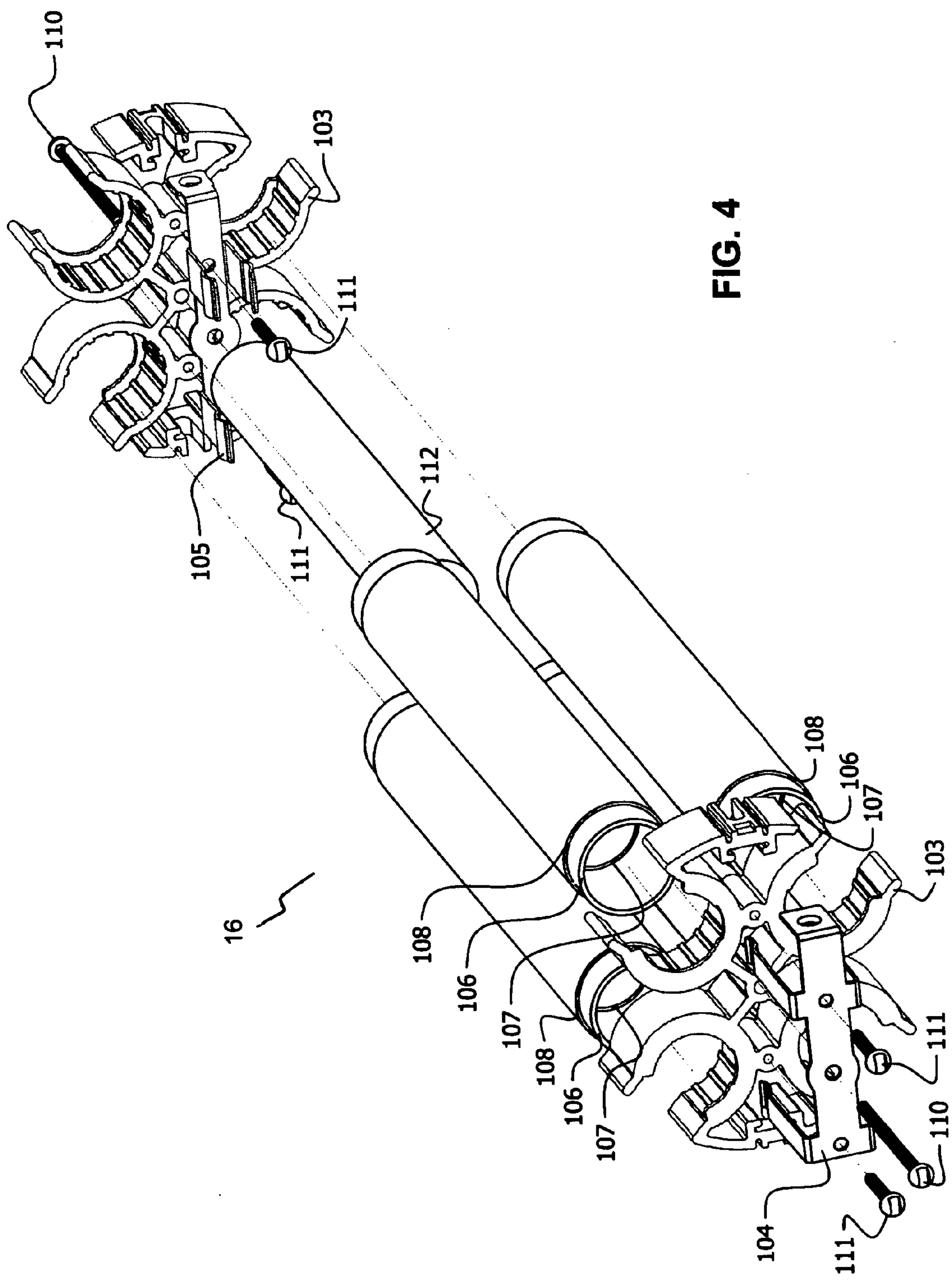

110
103
111
112
105
111
108
106
107
103
16
108
106
107
108
106
107
111
110
104
111

FIG. 4

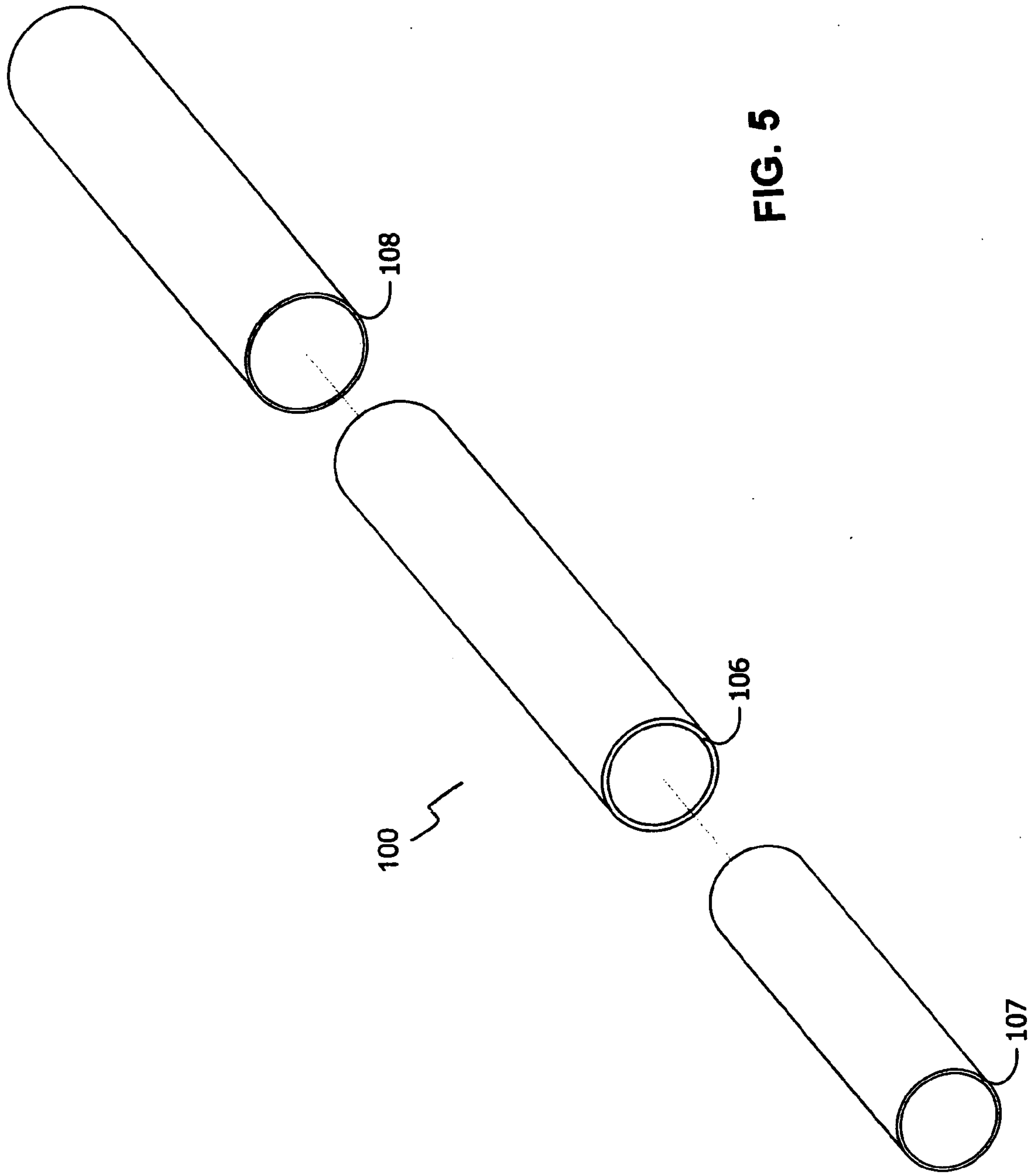


FIG. 5

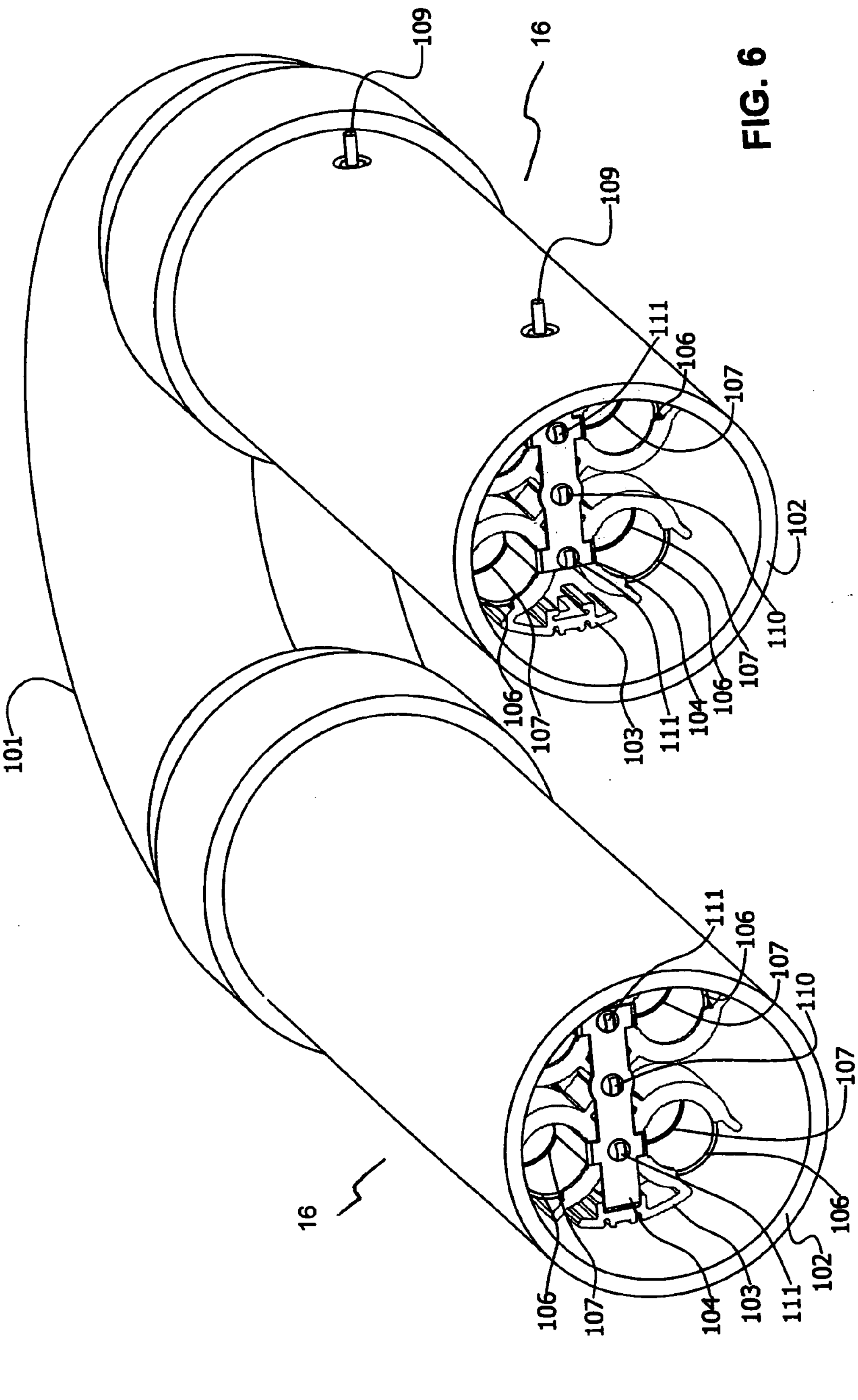

109
16
109
111
106
107
102
110
107
106
104
111
103
107
106
101
111
106
107
110
107
106
102
111
103
104
107
106
16

FIG. 6

APPARATUS AND METHOD FOR SANITIZING AIR AND SPACES

FIELD OF THE INVENTION

[0001] The present invention relates to a method and apparatus for sanitizing air and spaces through the generation of reactive oxygen species.

BACKGROUND OF THE INVENTION

[0002] Temperature changes and changes in the moisture in the air feeding into heating, ventilation, and air-conditioning (HVAC) systems increases the number micro-organisms in the air, producing increased colonies of certain fungi and bacteria, both of which are potentially harmful.

[0003] HVAC systems in office buildings, as well as hospitals, can be a source of various pathogens which spread infectious micro-organisms from one zone to another—a principal cause of Sick Building Syndrome, recognized by the World Health Organization as a threat to healthy work and living environments.

[0004] The purification of environments can be achieved through the use of ozone. Ozone has been used to purify air conditioning systems in buildings and to sanitize warehouses where products are stored. Despite its widespread use, this basic technique has the disadvantage of accumulating more ozone than is necessary in the treated environment, requiring the elimination of the excess ozone. Several different improvements in this method have been made in an attempt to control the levels of ozone in the environment being treated.

[0005] One such improvement provides high initial levels of ozone to the environment sufficient to produce the desired bacteriostatic or bacteriocidal effect. Later the levels of ozone are reduced so that they do not produce harmful effects to the products being treated or to humans in the environment.

[0006] However, the majority of the known systems for purifying closed areas with ozone are based on an ozone generator that utilizes a source of concentrated oxygen, for example bottled oxygen or a known pressurized oxygen generating system utilizing static discharge. When ozone is generated from a source of concentrated oxygen, the level of oxygen in the enclosure may rise along with the level of ozone. The increase in oxygen levels is due to the breakdown of ozone partially into new molecules of oxygen. An increase in the level of oxygen in enclosures containing natural perishable products enhances cellular metabolism and thus is detrimental to the storage of the perishable products.

[0007] One known method is applied to substantially closed rooms or rooms with a controlled atmosphere. The substantially closed room includes a closed circuit air conditioning system, such as a cooling system, for the preservation of perishable natural products. A known ozone generator is placed in proximity with the substantially closed room such that the ozone generator can draw in air from within the substantially closed room and liberate ozone into the substantially closed room. In contrast to other known ozonation systems, the known method utilizes oxygen from the air of the room in which the purification treatment is being applied to generate ozone. Because the method converts oxygen from the air into ozone, no increase in oxygen levels is observed in the closed room. Rather, the gaseous equilibrium is shifted so that there is maintenance of the level of oxygen in the enclosure.

[0008] The oxidative character of the ozone has a bacteriostatic and fungistatic effect in the short term, followed by a bacteriocidal and fungicidal effect. These effects combine with the lowered metabolism in a temperature cooled environment to reduce ripening, retard spoilage and thus preserve natural perishable products stored in the room.

[0009] However, the system does not provide an optimal means for efficiently sanitizing the air within the closed room.

SUMMARY OF THE INVENTION

[0010] Therefore, it is an object of the present invention to provide an apparatus and method for generating reactive oxygen species and treating the air to be sanitized with the generated reactive oxygen species in order to efficiently sanitize air.

[0011] To attain the above object, according to a first aspect of the invention, there is provided an apparatus for sanitizing air including a reaction unit for generating reactive oxygen species from oxygen in air received in the reaction unit to be sanitized, wherein airborne contaminants in the received air are substantially neutralized by the generated reactive oxygen species before the air is discharged from the reaction unit. Preferably, the air to be sanitized comprises ambient air.

[0012] Preferably, the reactive oxygen species generated include at least one of singlet oxygen, atomic oxygen, superoxide, hydrogen peroxide, hydroxyl radical, and peroxynitrite.

[0013] The reaction unit preferably further generates ozone from the oxygen in the air and the generated ozone is discharged with the air from the reaction unit, wherein the ozone in the sanitized air acts as a sanitizing agent for sanitizing surfaces.

[0014] Preferably, the apparatus further includes an ultraviolet light source for illuminating the air discharged from the reaction unit with ultraviolet light to neutralize at least a portion of the ozone in the discharged air.

[0015] The ultraviolet light source is preferably selectively controlled to regulate the ozone discharged from the reaction unit, and the ultraviolet light has a frequency between about 280 nm and 290 nm. Preferably, the ultraviolet light has a frequency of 285 nm.

[0016] The apparatus preferably further includes an intake port for the receiving air to be sanitized, and an exhaust port for discharging the substantially sanitized air, wherein the reaction unit is disposed between the intake port and the exhaust port.

[0017] Preferably, the apparatus further includes a power supply capable of a high frequency and high voltage output electrically coupled with the reaction unit to create a corona discharge which splits the oxygen in the air into reactive oxygen species.

[0018] The power supply preferably includes an onboard intelligence for enabling the power supply to adjust to changing conditions within the reaction unit. Preferably, the onboard intelligence permits the power supply to adjust levels of reactive oxygen species generated by the reaction unit.

[0019] The apparatus preferably includes a plurality of sensors for measuring at least one of ozone levels, humidity, airflow, and temperature, and a programmable logic circuit for measuring performance of the apparatus based on data feedback from the plurality of sensors.

[0020] The apparatus preferably further includes a controller operably linked to the reaction unit and the programmable logic circuit, wherein the performance of the apparatus may be regulated based on the data feedback from the plurality of sensors.

[0021] Preferably, a plurality of reaction units fluidly linked in a serial manner, wherein the air to be sanitized passes through the plurality of reaction units in order maximize exposure of the air to be sanitized to the reactive oxygen species.

[0022] Preferably, the reaction unit includes at least one reaction chamber in which the reactive oxygen species are generated.

[0023] The reaction unit preferably includes a plurality of reaction chambers. The plurality of reaction chambers are preferably held in place within an array by a coupler arranged on the plurality of reaction chambers.

[0024] Preferably, the coupler includes a clamp for securing each of the plurality of reaction chambers in a desired location within the array and an electrically conductive contact cooperatively shaped with the clamp and electrically contacting each of the plurality of reaction chambers in the array.

[0025] Preferably, the contact is integrally formed with the clamp, or the contact is attached to the clamp by one of an adhesive and a mechanical fastener.

[0026] The reaction unit preferably includes a center support included in the array and secured by the clamp to provide additional structural integrity to the array.

[0027] Preferably, the coupler cooperates with an inner surface of a housing of the reaction unit to secure the reaction chambers within the housing,

[0028] The array is preferably fixed within the housing using electrically conductive contact studs that interact with the coupler, the contact studs securing the array in relation to the housing and electrically connecting with an electrically conductive contact, wherein the contact is electrically connected to each of the plurality of reaction chambers.

[0029] Preferably, an electrical connection between the reaction chamber of the reaction unit and the power supply is achieved through the contact studs.

[0030] Preferably. the reaction chamber comprises a glass tube lined with an inner stainless steel mesh and wrapped in an outer stainless steel mesh.

[0031] A second aspect of the invention provides a method for sanitizing air including generating reactive oxygen species from oxygen in ambient air, and sanitizing a flow of ambient air using the generated reactive oxygen species.

[0032] Preferably, the reactive oxygen species generated include at least one of singlet oxygen, atomic oxygen, superoxide, hydrogen peroxide, hydroxyl radical, and peroxynitrite. Preferably, the reactive oxygen species generated further include ozone.

[0033] A third aspect of the invention provides a method for sanitizing a room including generating reactive oxygen species comprising ozone and at least one of singlet oxygen, atomic oxygen, superoxide, hydrogen peroxide, hydroxyl radical, and peroxynitrite from oxygen in ambient air, sanitizing air with the generated reactive oxygen species, introducing the generated ozone into the sanitized air, and discharging the sanitized air with ozone into the room to be sanitized, wherein the ozone in the sanitized air acts as a sanitizing agent for sanitizing surfaces of the room.

[0034] Preferably, the method further includes selectively illuminating the discharged air with ultraviolet light to neutralize at least a portion of the ozone in the discharged air, wherein an amount of ozone in the discharged air can be controlled.

[0035] Preferably, the ultraviolet light has a frequency between about 280 nm and 290 nm.

Preferably, the ultraviolet light has a frequency of 285 nm.

[0036] These and other exemplary features and advantages of the present invention will become clear from the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] The foregoing and other exemplary purposes, aspects and advantages will be better understood from the following detailed description of an exemplary embodiment of the invention with reference to the drawings, in which:

[0038] FIG. **1** shows a block diagram of the apparatus of the exemplary embodiment of the invention.

[0039] FIG. **2** shows a perspective view of an exemplary embodiment of the reaction unit of the invention.

[0040] FIG. **3** shows an exploded perspective view of the reaction unit of FIG. **2**.

[0041] FIG. **4** shows a further exploded perspective view of the reaction unit of FIG. **2**.

[0042] FIG. **5** shows an exploded perspective view of the reaction chamber of FIG. **2**.

[0043] FIG. **6** shows a perspective view of another embodiment of the reaction unit.

DETAILED DESCRIPTION OF THE INVENTION

[0044] Referring now to the drawings, and more particularly to FIGS. **1**-**6**, there are shown exemplary embodiments of the method and structures according to the present invention.

[0045] FIG. **1** shows an exemplary embodiment of the apparatus **10** for sanitizing air. The apparatus **10** includes an intake port **12** for receiving air to be sanitized and an exhaust port **14** for discharging substantially sanitized air. A reaction unit **16** is disposed between the intake port **12** and the exhaust port **14**. The reaction unit **16** generates reactive oxygen species from oxygen (O_2) in the air received through the intake port **12**.

[**0046**] The air received through the intake port **12** is preferably ambient air from the environment. The introduction of air into the reaction unit **16** may be mediated through a forced suction or by natural suction. When mediated through a forced suction, the apparatus **10** may contain a turbine which draws air into the reaction unit **16** through the intake port **12**. Preferably, the air is drawn through a filter to remove dust and other macroscopic impurities that may be present in the air to be sanitized before the air enters the reaction unit **16**.

[**0047**] The reaction unit **16** splits the oxygen in the air into large amounts of reactive oxygen species. The reactive oxygen species generated may include singlet oxygen ($1O_2$), ozone (O_3), atomic oxygen (O), superoxide (O_2—), hydrogen peroxide (H_2O_2), hydroxyl radical (OH—), and peroxynitrite (ONOO—). Even though many reactive oxygen species have a short half-life, they are effective sanitizing agents. Thus, as the air passes through the reaction unit **16**, a large percentage of the airborne contaminants in the air received through the intake port **12** are neutralized by the generated reactive oxygen species before the air is exhausted through the exhaust port **14**. In this manner, the reactive oxygen species generated in the reaction unit **16** act as a sanitizer of the air passing through the reaction unit **16**.

[**0048**] One of the reactive oxygen species generated by the reaction unit **16** is ozone (O_3). The generated ozone is introduced into the air in the reaction unit **16**, and the ozone also acts as a sanitizer of the air and environment. The ozone generated in the reaction unit **16** may be discharged with the air through the exhaust port **14**. The ozone in the discharged air provides the beneficial preservative effects and acts as a sanitizer for any surfaces in the environment into which the air is discharged. Other reactive oxygen species, such as hydrogen peroxide, may also be discharged with the sanitized air and have sanitizing effects similar to ozone.

[**0049**] The apparatus may include a power supply **18** capable of producing high frequency and high voltage output. The power supply **18** is electrically coupled with the reaction unit **16** to create a corona discharge which splits the oxygen in the air into large amounts of reactive oxygen species. The power supply **18** provides power to the reaction unit **16**.

[**0050**] The power supply **18** preferably includes an onboard intelligence **24** which enables the power supply **18** to adjust to changing conditions within the reaction unit **16**. In this manner, the levels of reactive oxygen species generated within the reaction unit **16** can be maintained at desired levels regardless of changing conditions within the reactor unit **16**. For example, the onboard intelligence **24** of the power supply **18** can compensate for variables that may affect the output of the reaction unit **16**, such as changes in moisture content of the air to be sanitized or dust buildup within the reactor unit **16**.

[**0051**] Further, the onboard intelligence **24** may allow for the dialing up and down of the levels of reactive oxygen species generated by the reaction unit **16**. Preferably, the amount of reactive oxygen species generated by the reaction unit **16** is adjustable while maintaining continuous power to the reaction unit **16**. However, one skilled in the art will recognize that the desired levels of reactive oxygen species may also be obtained by turning the reaction unit **16** on and off periodically.

[**0052**] The apparatus **10** may further include a source of ultraviolet (UV) light source **26** for illuminating the sanitized air discharged from the reaction unit **16** with UV light. By illuminating the discharged air with specific frequencies of UV light, it is possible to neutralize the ozone in the discharged sanitized air. In particular, UVB light having a frequency between about 280 nm and 290 nm will effectively neutralize the ozone. Preferably, the UV light source **26** emits UVB light having a frequency of 285 nm to achieve optimal neutralization of the ozone. In this manner, the UV light source **26** can turned on and off as necessary to regulate the ozone levels in the air ultimately discharged into the environment while maintaining high reactive oxygen species levels within the reaction unit **16** to permit continued sanitization of the air.

[**0053**] Thus, by placing the UV light source **26** downstream from the exhaust port **14**, the air may continue to be sanitized by the reactive oxygen species generated in the reaction unit **16**, while the ozone levels of the discharged air can be selectively controlled by using the UV light source **26** to neutralize the ozone in the discharged air. The apparatus **10** may further include an adjustable arm which can move the UV light source **26** so that it can be positioned for maximum effectiveness. The UV light source **26** may be configured using reflective surfaces in the form of a mirrored center array with concave light areas so that the UV light can be dispersed in a desired fashion, for example through the entire width of a duct, in order to maximize the ozone neutralization capability of the apparatus **10**.

[**0054**] The apparatus **10** may further include other means for neutralizing the generated ozone. For example, the apparatus may include a heat source or carbon filtration means to neutralize the ozone in the discharged air. Additionally, the apparatus **10** may include means for neutralizing any other generated reactive oxygen species that may be discharged with the sanitized air from the reaction unit **16**.

[**0055**] The apparatus **10** may further include a plurality of sensors and modules **28** located within the apparatus **10** and throughout the environment into which the sanitized air is discharged. The sensors and modules **28** are used to measure pertinent variables, such as ozone levels, humidity, airflow, and temperature of the air in and around the apparatus **10**. A programmable logic circuit (PLC) **30** may be used to measure the performance of the apparatus **10** based on data feedback from the plurality of sensors and modules **28**. The PLC **30** may store this information locally or report the information to a controller **32** which can be linked to the apparatus **10** and to a central monitor and monitoring system **34**, such as a computer or other dedicated device.

[**0056**] In this manner, the PLC **30** may be used to monitor and control multiple functions of the apparatus **10** and facilitate data collection, retention, and reporting of performance (such as ozone output, etc.). The PLC **30** may also be used to monitor and control the power supply **16** through the onboard intelligence **24**. Thus, the onboard intelligence **24** may use the feedback from the sensors and modules **28** to appropriately adjust the reaction unit **16** to provide the desired levels of reactive oxygen species.

[0057] The PLC **30** may be appropriately configured to make the information accessible to a remote computing device **38** over a network **36**. The network **36** may include any known communications or networking means, for example, a Wide Area Network (WAN), Local Area Network (LAN), Internet, Bluetooth®, or any wireless connection. Thus, the PLC **30** may permit regulation and diagnosis of the apparatus **10** remotely by the computing device **38** over the networking means **36**. It is to be understood that one or more of the onboard intelligence **24**, PLC **30**, controller **32**, and monitoring system **34**, or functions thereof, may be provided on a single appropriately configured computing device for monitoring and controlling the functions of the apparatus **10**.

[0058] FIGS. **2-4** shows perspective and exploded views of an exemplary embodiment of the reaction unit **16** of the invention. The reaction unit **16** may consist of one or more reaction chambers **100** in which the reactive oxygen species are generated. The reaction chambers **100** may be arranged in an array within a housing **102**. The housing **102** may consist of round polyvinyl chloride (PVC) pipe of appropriate size. However, it is understood that the housing may be of any desired shape or material. For example, the housing **102** may consist of the duct work of an HVAC system.

[0059] Preferably, the reaction chambers **100** are held in place within the array by a coupler arranged on both ends of the reaction chambers **100**. The coupler may include a clamp **103** for securing the reaction chambers **100** in a desired location within the array. A center support rod **112** may be included in the array and appropriately secured by the clamp **103** to provide additional structural integrity to the array. The coupler may further include an electrically conductive contact **104**,**105** cooperatively shaped with the clamp **103** and contacting each of the reaction chambers **100** within the array. The contact **104** may be integrally formed with the clamp **103** or mechanically attached to the clamp **103** by an adhesive or mechanical fasteners **111**.

[0060] The coupler preferably cooperates with an inner surface of the housing **102** to secure the reaction chambers **100** within the housing **102**. The array may be fixed within the housing **102** using contact studs **109**. The electrically conductive contact studs **109** pass through the housing **102** and interact with the coupler so as to fixedly secure the clamp **103** in relation to the housing **102** and electrically connect with the contacts **104**,**105**. In this manner, the necessary electrical connections between the reaction chamber **100** of the reaction unit **16** and the power supply **18** may be achieved through the contact studs **109**. However, one of ordinary skill in the art will recognize that the necessary electrical connections may be achieved by multiple means.

[0061] As shown in FIG. **5**, the reaction chamber **100** may consist of a glass tube **106** lined with an inner stainless steel mesh **107** and wrapped in an outer stainless steel mesh **108**. This configuration has been found to create a very effective corona that is able to generate a large amount of reactive oxygen species without using a static discharge and without producing material amounts of off gases, such as nitrous oxide. While a round configuration for the reaction chamber is shown, the reaction chambers for generating reactive oxygen species may include different configurations and materials. For example, the reaction chambers may be formed of a glass tube **106** wrapped in stainless steel mesh with a copper tube coated with gold inside the glass tube at specific gaps. The reaction chambers may also be formed using appropriately configured plates of glass, ceramic or other materials with metal mesh on opposite sides. The particular configuration may be chosen to comport with the desired application of the apparatus **10**.

[0062] As shown in FIG. **6**, the apparatus **10** may include a plurality of reaction units **16** fluidly linked in a serial manner. In this manner, the air to be sanitized may be passed through multiple reaction units **16** in order to maximize the exposure of air to the reactive oxygen species, therefore greatly increasing the effective sanitation of the air. While a U-shape is shown, it is understood that the reaction units **16** may be arranged in any manner depending on the space constraints of the desired application of the apparatus **10**.

[0063] The reaction units **16** may be linked using an appropriate connector **101** that links the housings **102** of the reaction units **16**. The reaction units **16** may be linked using a butt-plate. The butt-plate may include all the necessary electrical connections for the reaction units **16** to eliminate high-voltage wiring and avoid wiring problems. This also makes servicing the apparatus **10** more streamlined and efficient. The necessary electrical connections between the reaction units **16** may be achieved using military lock in rotation connectors connecting the butt-plate **24** and reaction units **16**. Additionally, each reaction unit **16** may have its own power supply **18** in order to make the apparatus **10** highly scalable.

[0064] The apparatus **10** may be configured for general room sanitization applications where the apparatus **10**, or components thereof, may be placed in the duct work of an HVAC system servicing the room to be sanitized. Alternatively, the apparatus **10** may be incorporated into the HVAC system of a facility to generally sanitize the air in the facility. Additionally, the apparatus **10** may be used to sanitize air to be introduced to a room from an outside source (make up air), as well as to treat exhaust air to remove smells and contaminants before releasing the air into the environment.

[0065] The apparatus **10** may be placed directly into a duct of an HVAC system so that some of the components are external to the duct in order to balance or reduce the weight of the apparatus **10** and create less stress on the duct work. For example, one or more reaction units **16** may be placed in the duct so that the air in the duct flows directly through the reaction unit **16** resulting in the generated reactive oxygen species sanitizing the air passing through, and the generated ozone cleaning the duct and being dispersed into the environment. As described above, a UV light source **26** may be placed downstream from the reaction units **16** in the duct to regulate the dispersion of ozone into the environment.

[0066] The level of ozone maintained in the environment into which the sanitized air containing ozone is dispersed, for example a room or building, may vary from as low as 0.02 PPM to higher levels depending on regulations and safe operating conditions based on human presence. One skilled in the art will realize that the optimum level will be determined based on the size, configuration, and contents of the room. Further, one skilled in the art will recognize that the levels of ozone maintained in the environment used by people may be limited by governmental regulation. For example, OSHA regulations stipulate that eight hours of exposure to 0.1 PPM ozone is acceptable and that fifteen minutes of exposure to 0.3 PPM ozone is acceptable. Use of higher concentrations may be dangerous. In the preferred embodiment, the level of ozone will be controlled and maintained, for example by the PLC **30**, in accordance with governmental regulations. Higher levels of reactive oxygen species and ozone may be used during unoccupied periods for additional sanitation.

[**0067**] While the description refers to sanitizing air to be discharged into a room, space, or environment, it is to be understood that the invention can be applied to any defined environment. For example, an environment may be defined by solid surfaces or barriers, such as walls or product packaging, or defined by streams of forced gases, such as air screens or air curtains. Alternatively, the environment may be simply defined by the specific requirements of a desired application of the invention.

[**0068**] An exemplary application of the apparatus **10** would be for sanitizing sensitive areas of medical facilities, such as acute care areas and operating rooms. For example, the air circulation system of an operating room may include a network of ducts and vents that allow for the circulating of the air within the room without taking in air from outside the room. The apparatus **10**, or elements thereof, may be placed in the duct work so that the air in the operating room may circulate through one or more reaction units **16**. By including a UV light source **26**, when the room is in use, the UV light source **26** may be turned on to prevent ozone from being dispersed in the room. But when the room is not occupied, the UV light source **26** may be turned off, allowing the generated ozone to circulate throughout the room and remove contaminants from surfaces inside the room. It is to be understood that the apparatus **10** may be employed in a wide variety of medical applications. For example, the sterilization of medical equipment storage cabinets and rooms, such as endoscope cabinets, and the sanitization of other rooms of medical facilities, such as waiting rooms, bathrooms, and food production areas.

[**0069**] In a similar manner, the apparatus **10** may be utilized in food processing environments to sanitize the air while food is being processed with workers present, provide the beneficial preservative effects of ozone while food is being stored (before and after processing), and sanitize the air and surfaces while the processing room is vacant. The apparatus **10** may also be configured into food processing equipment so that food is treated as it moves through the equipment, for example on a conveyor belt, automatic cutters and slicers and inspection areas. The product may be tumbled to promote uniform treatment. The apparatus **10** may also be configured to be placed in containers, trailers, and rail cars or as a component to a refrigeration system of such containers, trailers, and rail cars to sanitize the air therein while providing the beneficial preservative effects of ozone to any products stored therein.

[**0070**] Other exemplary applications of the apparatus include the provision or incorporation of the apparatus **10** into: grocery store display cases, such as deli counters and meat, fish and poultry display cases; floral display cases, both refrigerated and non-refrigerated; and HVAC systems of various public transportation means, such as cars, buses, trains, subways, or aircraft. The invention may be employed in pressurized environments, such as aircraft and positively or negatively pressurized rooms and structures. The apparatus **10** may also be incorporated into packing and production line equipment that blows air into bags as products are packed and sealed to sanitize the air blown into the bag and preserve the product therein, or into equipment that is integrated into a production line to sanitize the air and product before packaging.

[**0071**] As noted above, the apparatus **10** may also be incorporated into the HVAC system of public buildings in order to generally treat the air within the buildings. In this manner, the apparatus **10** may be used to sanitize the air and eliminate odors in the buildings. For example, office buildings, restaurants, malls, and the like would be particularly appropriate applications due to the large numbers of people that occupy the buildings and the need to sanitize the air in the buildings to provide a healthier, cleaner and more desirable environment for the occupants. The apparatus **10** may further be employed to sanitize air that is to be exhausted out of buildings in order to eliminate or reduce contaminants and odors emitted from the building into the surrounding environment.

[**0072**] In another exemplary application of the invention, the apparatus **10** may include sensors **28** for detecting potentially harmful agents in the environment. For example, the apparatus **10** may be incorporated into an HVAC system of a building and include appropriate sensors **28** for detecting noxious chemical or biological agents that may be unlawfully or accidentally released in or around the building. The apparatus **10** may be appropriately controlled to automatically operate in response to a positive detection of such agents by the sensor **28** in order to sanitize the air and protect the occupants of the building from the harmful agents.

[**0073**] In yet another application of the invention, the sanitized air discharged into the environment may be directed through a nozzle or jet to permit directional control of the sanitized air. In this manner, the sanitized air can be actively directed to a specific location or area requiring the sanitizing effect of the discharged air. Similarly, the invention may be incorporated into a means for creating air curtains or air doors. For example, an air curtain can be created to substantially enclose a specified space in order to contain and control any undesirable odors or emissions from contents within the created space, or, alternatively, sanitize or preserve the contents within the created space.

[**0074**] In a further exemplary application of the invention, the apparatus **10** may be incorporated into vacuum cleaner devices, for example stand-alone or centralized vacuum cleaners, wet-dry vacuums, and carpet cleaners, in order to sanitize air discharged from the cleaner. In this manner, any contaminants and odors inhaled by the cleaner would be sanitized and not discharged into the environment in which the cleaner was being utilized.

[**0075**] While the invention has been described in terms of several exemplary embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

[**0076**] Further, it is noted that, Applicant's intent is to encompass equivalents of all claim elements, even if amended later during prosecution.

What is claimed is:

1. An apparatus for sanitizing air comprising:

a reaction unit for generating reactive oxygen species from oxygen in air received in the reaction unit to be sanitized,

wherein airborne contaminants in the received air are substantially neutralized by the generated reactive oxygen species before the air is discharged from the reaction unit.

2. The apparatus of claim 1, wherein the reactive oxygen species generated comprise at least one of singlet oxygen, atomic oxygen, superoxide, hydrogen peroxide, hydroxyl radical, and peroxynitrite.

3. The apparatus of claim 2, wherein the reaction unit further generates ozone from the oxygen in the air and the generated ozone is discharged with the air from the reaction unit, wherein the ozone in the sanitized air acts as a sanitizing agent for sanitizing surfaces.

4. The apparatus of claim 3, further comprising:

an ultraviolet light source for illuminating the air discharged from the reaction unit with ultraviolet light to neutralize at least a portion of the ozone in the discharged air.

5. The apparatus of claim 4, wherein the ultraviolet light source is selectively controlled to regulate the ozone discharged from the reaction unit.

6. The apparatus of claim 4, wherein the ultraviolet light has a frequency between about 280 nm and b **290** l nm.

7. The apparatus of claim 4, wherein the ultraviolet light has a frequency of 285 nm.

8. The apparatus of claim 1, further comprising:

an intake port for the receiving air to be sanitized; and

an exhaust port for discharging the substantially sanitized air,

wherein the reaction unit is disposed between the intake port and the exhaust port.

9. The apparatus of claim 1, further comprising:

a power supply capable of a high frequency and high voltage output electrically coupled with the reaction unit to create a corona discharge which splits the oxygen in the air into reactive oxygen species.

10. The apparatus of claim 9, wherein the power supply comprises an onboard intelligence for enabling the power supply to adjust to changing conditions within the reaction unit.

11. The apparatus of claim 12, wherein the onboard intelligence permits the power supply to adjust levels of reactive oxygen species generated by the reaction unit.

12. The apparatus of claim 1, further comprising:

a plurality of sensors for measuring at least one of ozone levels, humidity, airflow, and temperature; and

a programmable logic circuit for measuring performance of the apparatus based on data feedback from the plurality of sensality of sensors.

13. The apparatus of claim 12, further comprising:

a controller operably linked to the reaction unit and the programmable logic circuit, wherein the performance of the apparatus may be regulated based on the data feedback from the plurality of sensors.

14. The apparatus of claim 1, wherein the air to be sanitized comprises ambient air.

15. The apparatus of claim 1, further comprising:

a plurality of reaction units fluidly linked in a serial manner, wherein the air to be sanitized passes through the plurality of reaction units in order maximize exposure of the air to be sanitized to the reactive oxygen species.

16. The apparatus of claim 1, wherein the reaction unit comprises at least one reaction chamber in which the reactive oxygen species are generated.

17. The apparatus of claim 16, wherein the reaction unit comprises a plurality of reaction chambers.

18. The apparatus of claim 17, wherein the plurality of reaction chambers are held in place within an array by a coupler arranged on the plurality of reaction chambers.

19. The apparatus of claim 18, wherein the coupler comprises a clamp for securing each of the plurality of reaction chambers in a desired location within the array.

20. The apparatus of claim 19, wherein the reaction unit further comprises a center support included in the array and secured by the clamp to provide additional structural integrity to the array.

21. The apparatus of claim 19, wherein the coupler comprises an electrically conductive contact cooperatively shaped with the clamp and electrically contacting each of the plurality of reaction chambers in the array.

22. The apparatus of claim 21, wherein the contact is integrally formed with the clamp.

23. The apparatus of claim 21, wherein the contact is attached to the clamp by one of an adhesive and a mechanical fastener.

24. The apparatus of claim 18, wherein the coupler cooperates with an inner surface of a housing of the reaction unit to secure the reaction chambers within the housing.

25. The apparatus of claim 24, wherein the array is fixed within the housing using electrically conductive contact studs that interact with the coupler, the contact studs securing the array in relation to the housing and electrically connecting with an electrically conductive contact, wherein the contact is electrically connected to each of the plurality of reaction chambers.

26. The apparatus of claim 25, wherein an electrical connection between the reaction chamber of the reaction unit and the power supply is achieved through the contact studs.

27. The apparatus of claim 16, wherein the reaction chamber comprises a glass tube lined with an inner stainless steel mesh and wrapped in an outer stainless steel mesh.

28. A method for sanitizing air comprising:

generating reactive oxygen species from oxygen in ambient air; and

sanitizing a flow of ambient air using the generated reactive oxygen species.

29. The method of claim 28, wherein the reactive oxygen species generated comprise at least one of singlet oxygen, atomic oxygen, superoxide, hydrogen peroxide, hydroxyl radical, and peroxynitrite.

30. The method of claim 29, wherein the reactive oxygen species generated further comprise ozone.

31. A method for sanitizing a room, comprising:

generating reactive oxygen species comprising ozone and at least one of singlet oxygen, atomic oxygen, superoxide, hydrogen peroxide, hydroxyl radical, and peroxynitrite from oxygen in ambient air;

sanitizing air with the generated reactive oxygen species;

introducing the generated ozone into the sanitized air; and

discharging the sanitized air with ozone into the room to be sanitized, wherein the ozone in the sanitized air acts as a sanitizing agent for sanitizing surfaces of the room.

32. The method of claim 31, further comprising

selectively illuminating the discharged air with ultraviolet light to neutralize at least a portion of the ozone in the discharged air, wherein an amount of ozone in the discharged air can be controlled.

33. The method of claim 32, wherein the ultraviolet light has a frequency between about 280 nm and 290 nm.

34. The method of claim 32, wherein the ultraviolet light has a frequency of 285 nm.

* * * * *