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(54) APPARATUS AND METHOD FOR INHIBITING THE GROWTH OF MICROBIOLOGICAL ORGANISMS IN COMMERCIAL ICEMAKERS AND COOLERS

(76) Inventors: **Roy E. Seibert**, McKinney, TX (US); **Kevin Ezell**, Dallas, TX (US)

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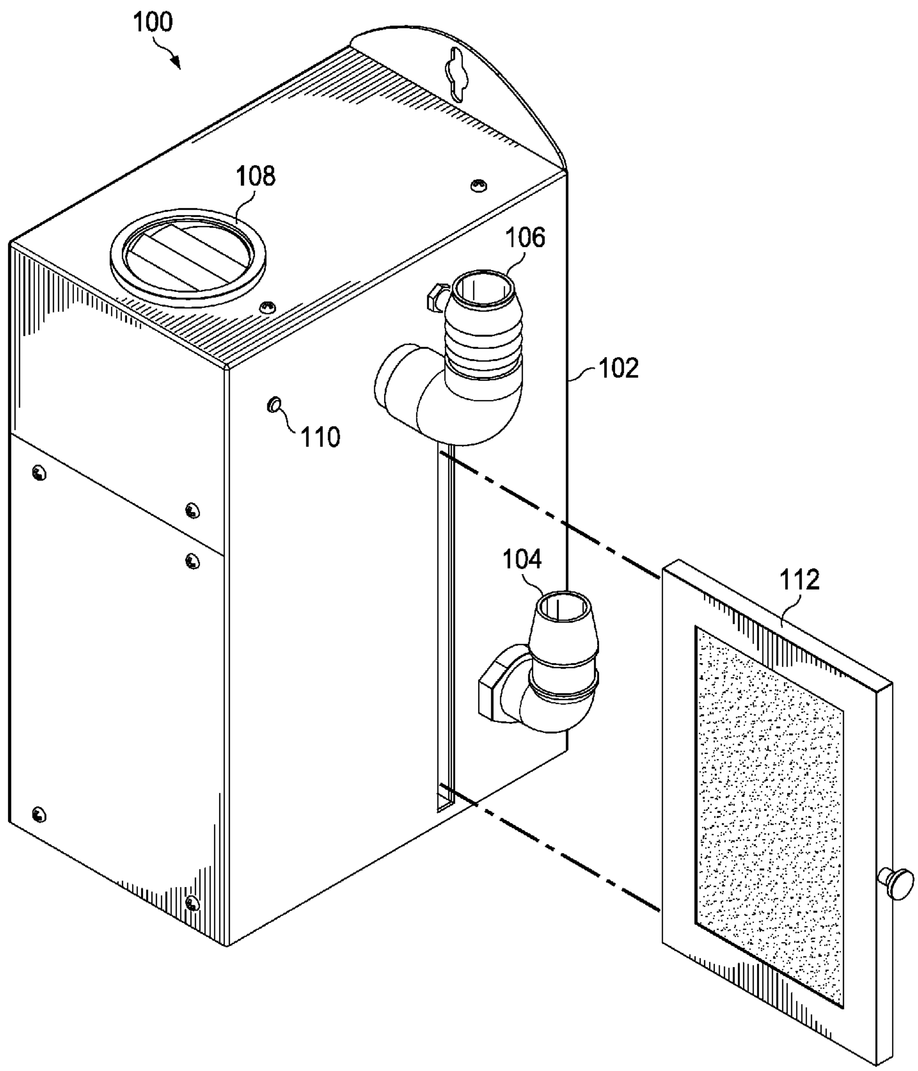
(57) **ABSTRACT**

An apparatus for inhibiting the growth of microbiological organisms in commercial icemakers and coolers by treatment of the air within the device evaporator air space. The apparatus includes a mechanical filtration device, a PCO device, and a UV light device. Air is drawn from the evaporator space, mixed with a small amount of ambient air from around the apparatus, and mechanically filtered to remove particulates. The filtered air is then passed through the PCO device that is activated by the UV light device, where it is treated by the ROS produced by the activated PCO device. A UV light further produces ROS to treat the filtered air stream, which is returned to the internal space of the commercial refrigeration device. Recirculation of the treated air increases residence time. The addition of a small amount of external air with the internal air allows for positive pressurization of the evaporator space.



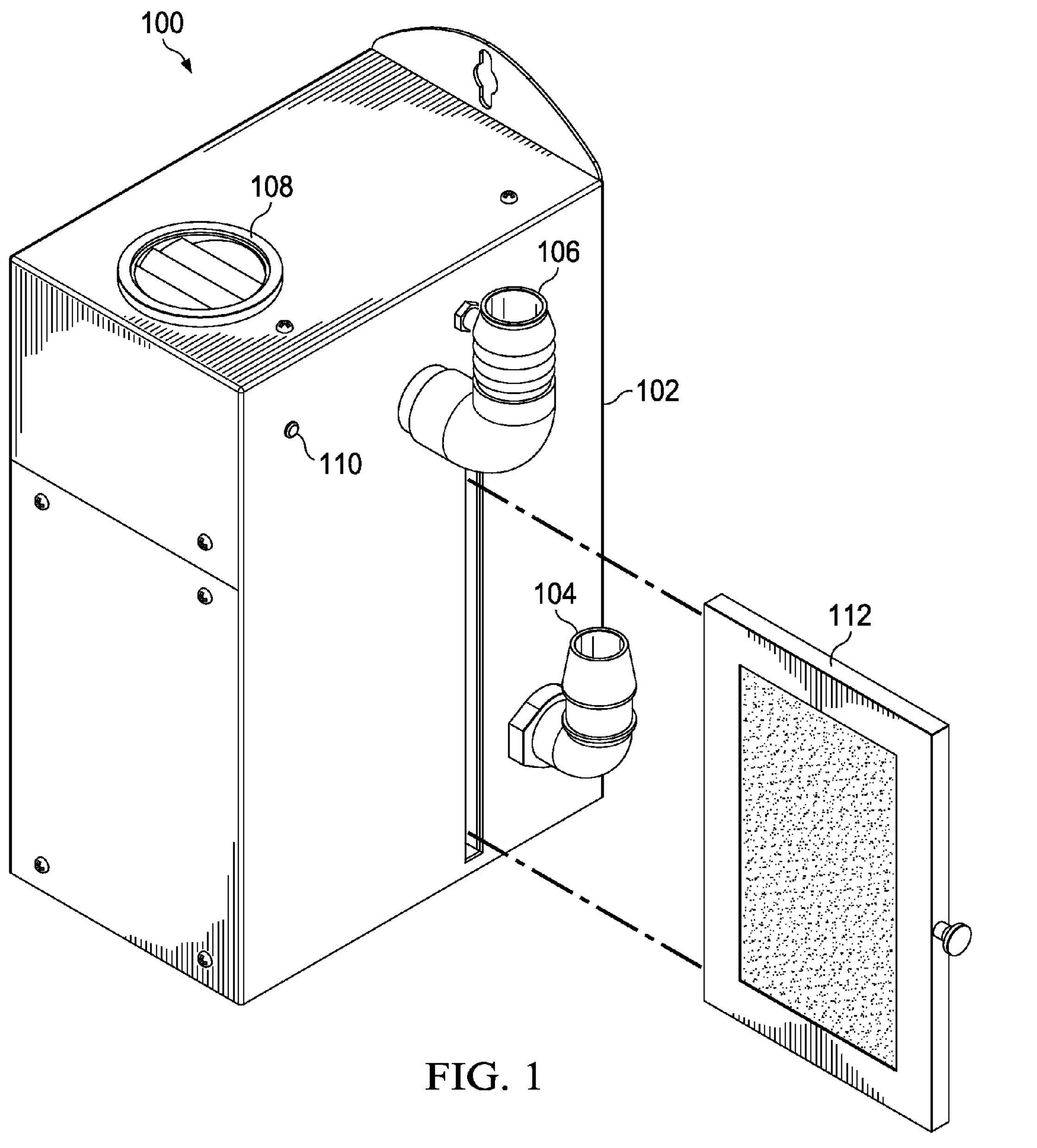
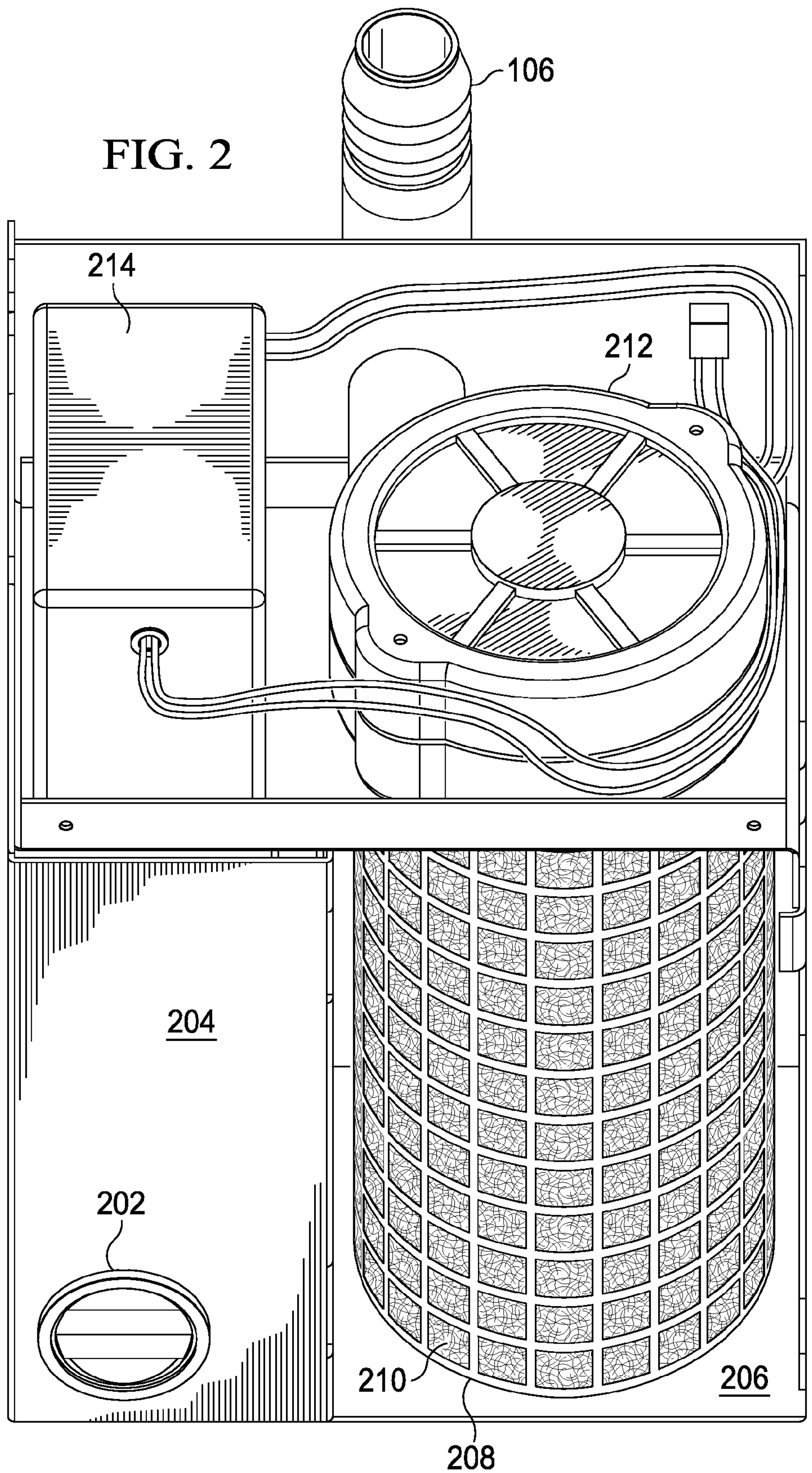


FIG. 1

FIG. 2



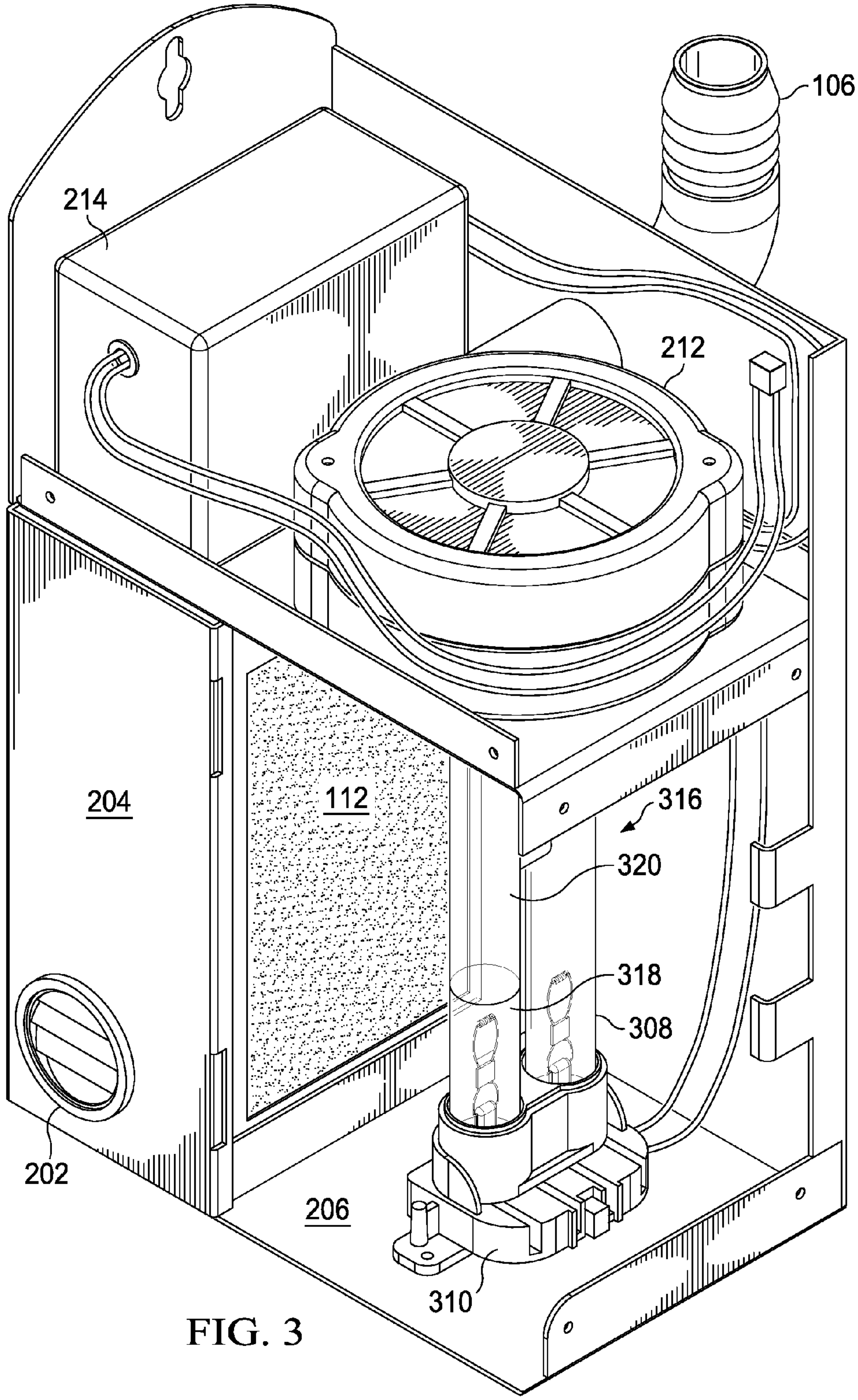


FIG. 3

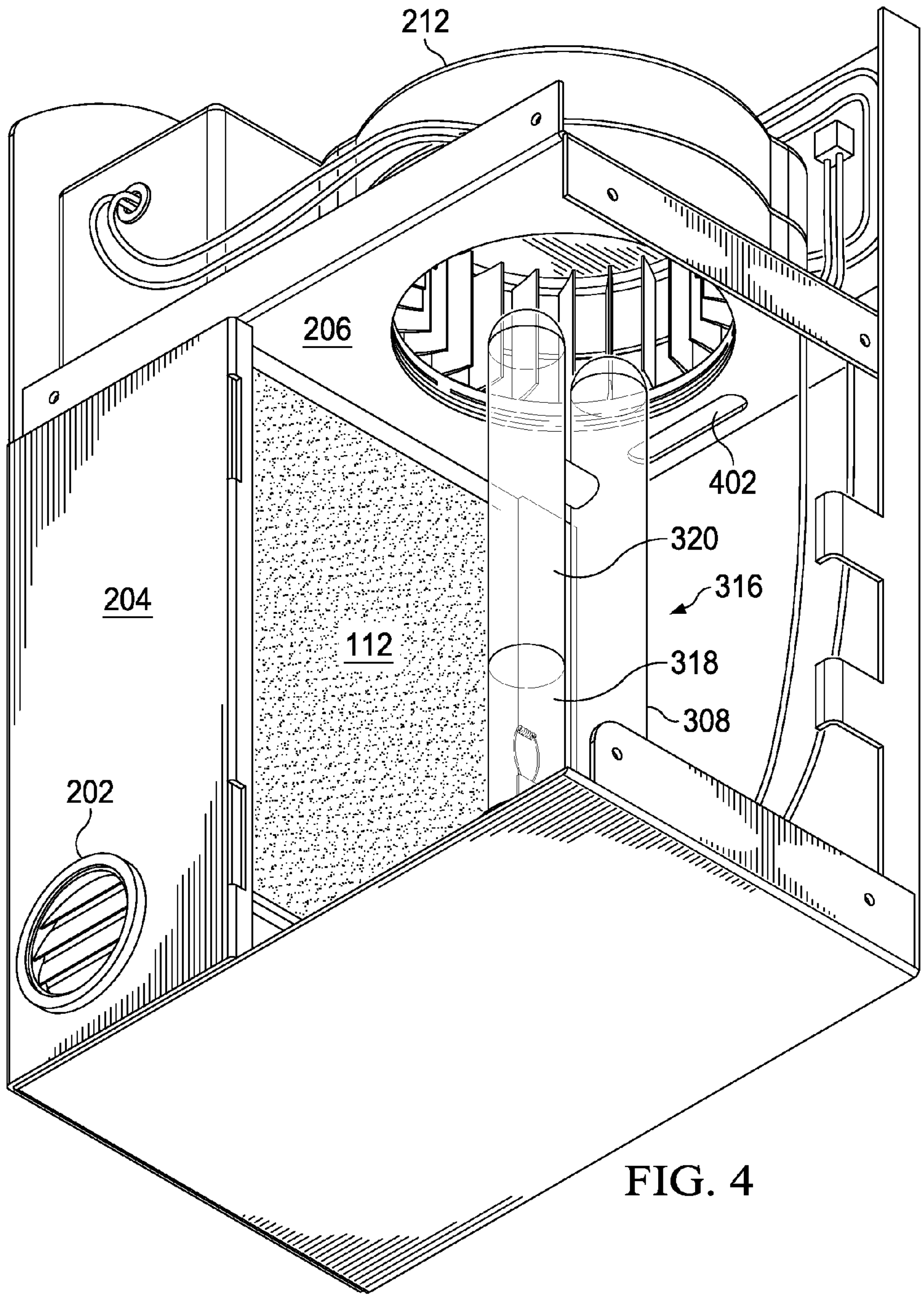


FIG. 4

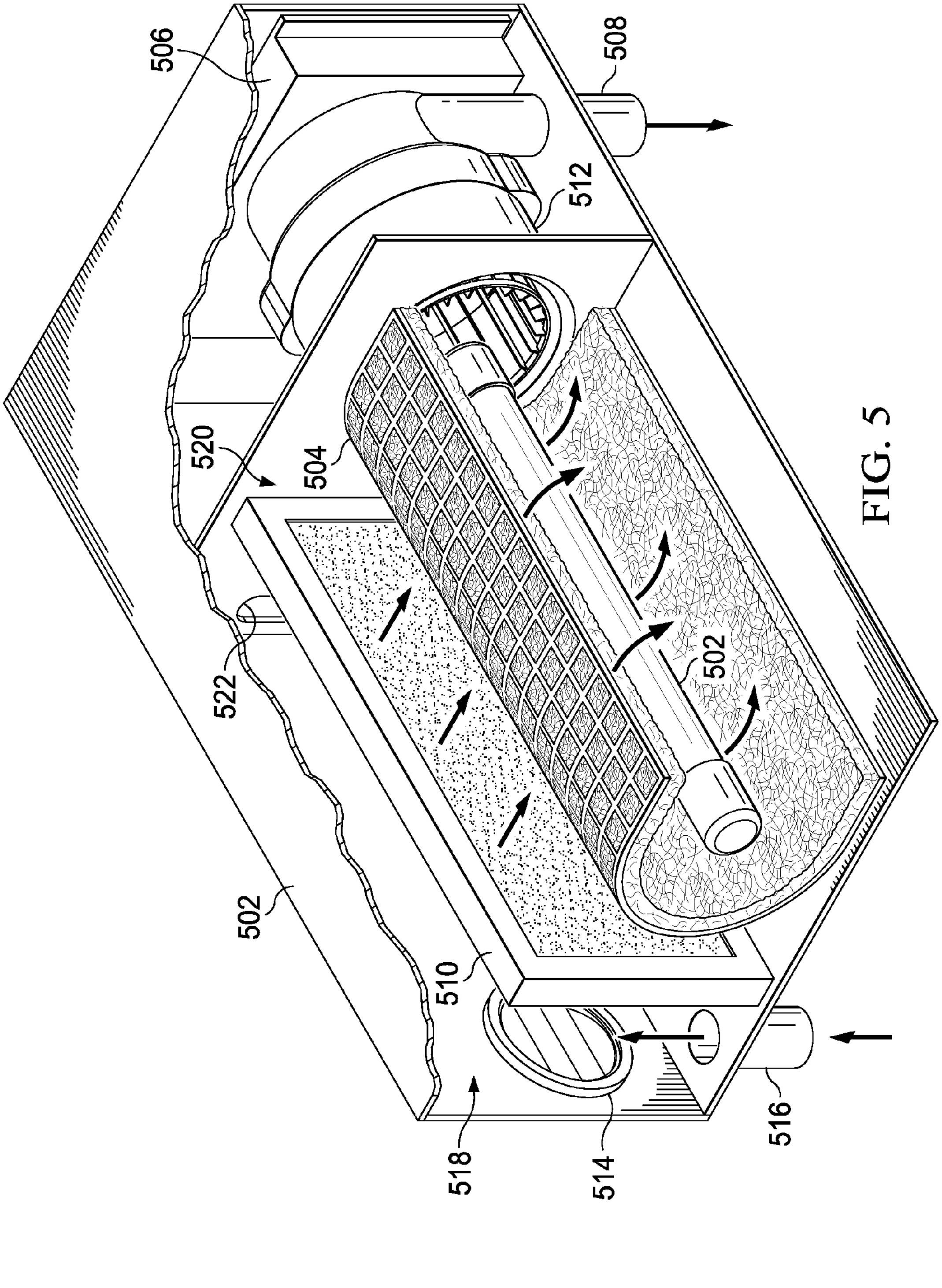


FIG. 5

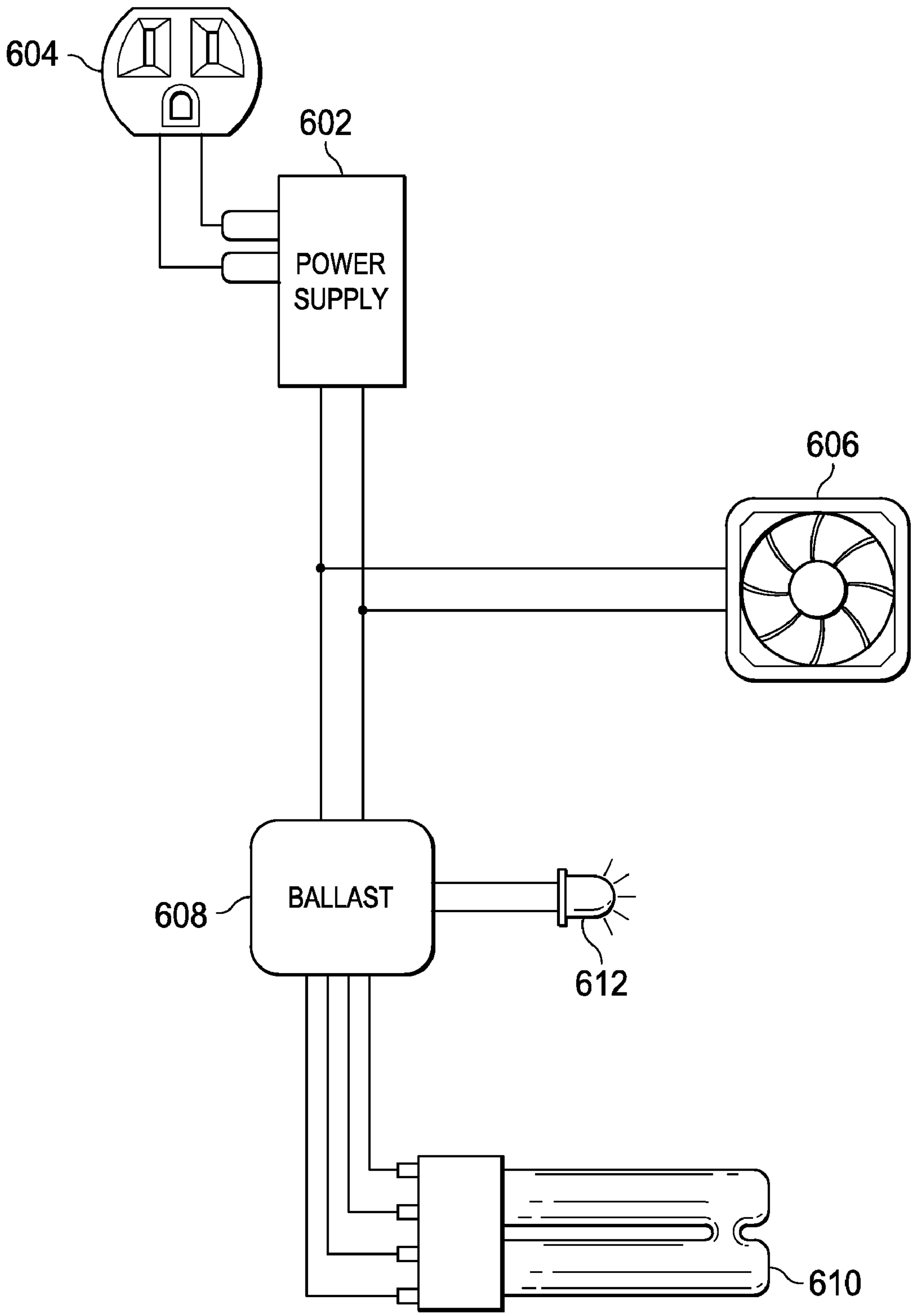


FIG. 6

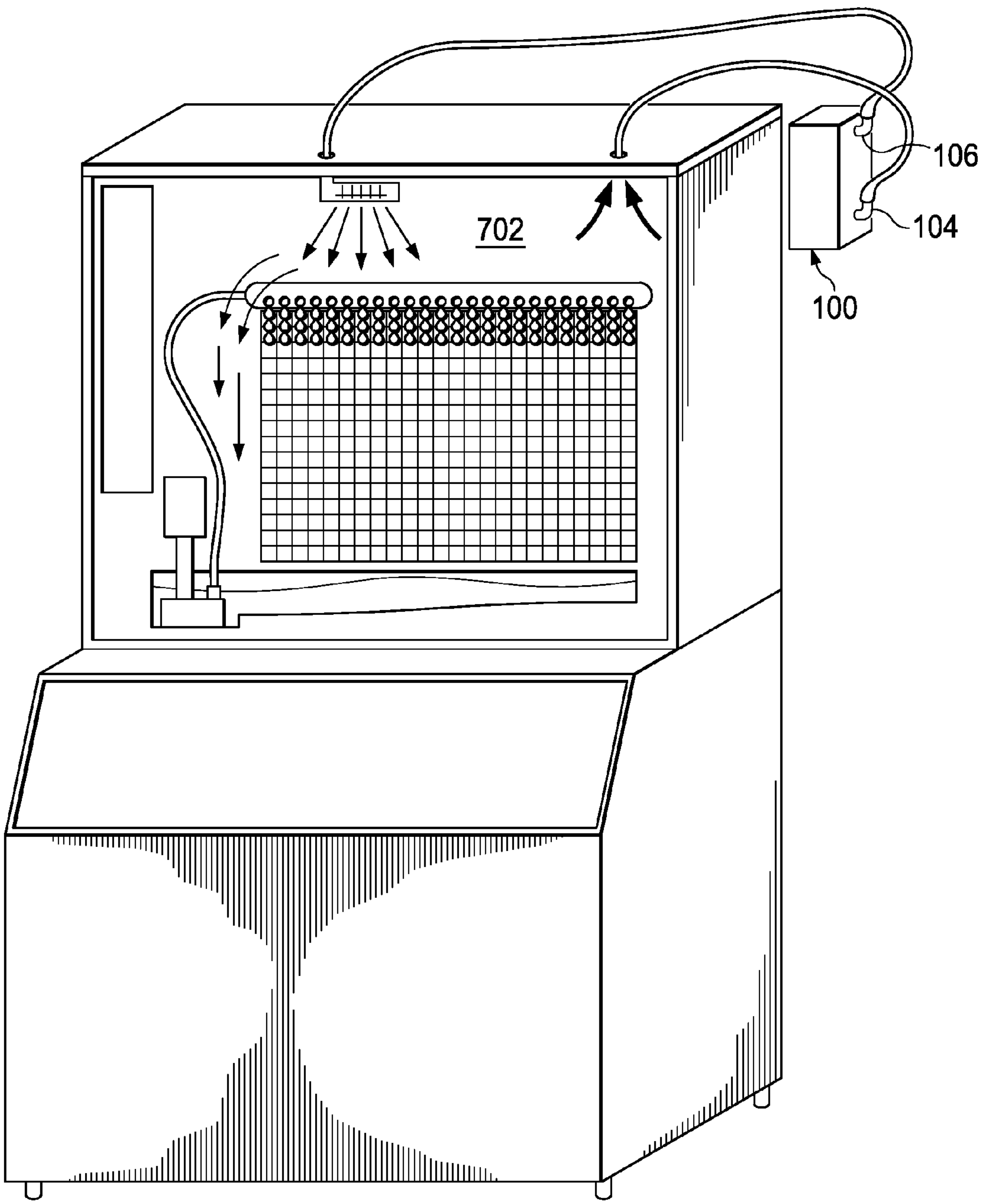


FIG. 7

APPARATUS AND METHOD FOR INHIBITING THE GROWTH OF MICROBIOLOGICAL ORGANISMS IN COMMERCIAL ICEMAKERS AND COOLERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of provisional Application No. 61/487,356, which was filed on May 18, 2011.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

THE NAMES OF THE PARTIES TO A JOINT RESEARCH AGREEMENT

[0003] Not Applicable

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

[0004] Not Applicable

BACKGROUND OF THE INVENTION

[0005] 1. Field of the Invention

[0006] The present invention relates to fluid filtration and purification and, more specifically, to a device, system, and method for filtration and purification of the atmosphere within a commercial icemaker or cooler.

[0007] 2. Description of Related Art including information disclosed under 37 CFR 1.97 and 1.98

[0008] Biological growth due to yeast, mold, bacteria and other water-borne and airborne contaminants in the evaporator areas and storage bins of icemakers is an ongoing problem, especially when such machines are used in environments conducive to biological growth—such as restaurants that make bread products or store quantities of empty beer bottles. This problem is exacerbated by workers' frequent access to the icemaker's storage bin to remove ice cubes. Moreover, bio-growth tends to proliferate in the wet zone areas of the icemaker where water is splashed or where condensate forms—more so than in the water sump itself. Thus, it is common to find biological growth on the sides of the evaporator grids, distribution piping, in areas where condensate occurs, and in the bottom of the storage bins.

[0009] Historically, the incoming water has been targeted as the ultimate source of the problem. Various efforts to control the problem with forms of water treatment have been attempted, including sub-micron filtration, silver-impregnated filtration media, ultra-violet light, ozone, reverse-osmosis, or some combination of these. However, treating the water that is contained in the icemaker sump and recirculated to the evaporator has had minimal impact on the problem and has not provided effective protection to the splash zones, condensate areas and ice storage bin from air-borne biological organism growth.

[0010] Attempts have been made to eradicate air-borne biological organisms by using air filters, ultraviolet light, ozone, hydroxyl ions, photocatalytic oxidation, and chlorine dioxide. However, such attempts have had minimal impact and have even resulted in damage to equipment and reduced-quality ice due to the negative and harmful by-products. In some cases designs that utilize ultraviolet light, ozone or chlorine dioxide (all strong oxidizers) have adversely impacted plastics and elastomers in the equipment, resulting in detrimental degradation of the materials and leading to overall equipment failures.

[0011] Ozone-producing UV bulbs coated with Titanium Dioxide to create hydroxyl ions have been tried under the theory that hydroxyl ions will migrate into the icemaker and reduce bio-growth. However, it is a fact that hydroxyl ions are highly reactive and do not last long enough to migrate more than a few millimeters away from the UV bulb or other such surface where they are produced. Typically, the only reactive oxygen species that migrates downstream from such a bulb is ozone, while most of the air-borne contaminants flowing through the device never come into contact with the hydroxyl ions created by such a titanium-dioxide coated UV bulb. Moreover, such a titanium dioxide coated UV bulb provides a minimal amount of surface area relative to the volume of air contained within the device (approximately 12.30 square inches), which provides inadequate exposure and contact between hydroxyl ions and airborne contaminants passing through the icemaker. Other attempts have treated the inside surface of the UV bulb chamber with a titanium dioxide layer to leverage the greater surface area surrounding the bulb. However, this still falls far short of treating the passing air because, once again, the hydroxyl ions are produced on and remain very near the surface of the treated chamber walls, never reaching the bulk of the air-borne contaminants flowing through the chamber.

[0012] Commercial icemakers are routinely engineered and designed using plastics, elastomers and other materials that are highly susceptible to damage from UV light or ozone. Uncontrolled, direct exposure to UV light or high levels of ozone degrade materials in icemakers including wire insulation, hoses, plastic fittings, wire ties, etc. Discoloration and brittleness of these materials is often observed in a relatively short period of time upon exposure. Further, OSHA and other regulatory agencies have established limits for workplace exposure to ozone for both short-term and long-term exposure, yet the ozone levels required to eliminate biological growth on surfaces within an icemaker far exceed the recommended allowable human exposure levels.

[0013] Entry within the icemaker of contaminated external air further complicates the issue. For example, most commercial icemakers locate the refrigeration compressor motor and cooling fan adjacent to the evaporator area where the ice cubes are produced. The cooling fan, designed to draw outside air through the cooling fins, causes the influx of external air into the ice cube bin and evaporator area through small gaps in the icemaker enclosure, particularly in gaps found around these specific areas. External air is rarely pure and essentially always contains biological organisms that collect and proliferate on the internal surfaces of the icemaker.

[0014] Current purification devices exacerbate this external-air contamination by increasing the negative pressure within the icemaker. For example, the device depicted in U.S. Publication No. 2009/0142225 (the "225 publication") teaches an ozone generator device for ice machines (FIGS. **7**, **16**, and **17**). As clearly described therein, this device utilizes a fan to draw air from the icemaker interior where it passes through the device chamber. Within the device chamber is a UV bulb that is coated to allegedly produce ozone. Both the fan and the UV bulb require control circuitry for operation, with the totality of these components (control circuitry included) producing considerable heat. A portion of the air drawn into the device chamber is used to cool these hot components and, instead of returning this air to the icemaker interior where it would likely melt the ice, this heated air is discharged to the atmosphere in the space outside the icemaker. The remaining air that was passing through the device chamber returns to the icemaker interior. However, the amount of remaining air returning to the icemaker interior is substantially less than the air that was drawn from the icemaker interior, resulting in a negative pressure within the icemaker. Again, this negative pressure causes an inflow of external, untreated contaminated air to the icemaker interior, introducing yet additional biological and other air-borne contaminants.

[0015] These shortcomings and others are addressed by the embodiments described herein, as will be appreciated by one of ordinary skill in the art following a review and understanding of the detailed disclosure provided.

BRIEF SUMMARY OF THE INVENTION

[0016] One embodiment provides an apparatus for inhibiting the growth of microbiological organisms in a commercial icemaker or refrigeration device, the apparatus comprising: an inlet plenum in fluid communication with a treatment plenum, the inlet plenum accepting air from the evaporator air space of an icemaker or refrigeration device, the inlet plenum further accepting ambient air from the air space surrounding the apparatus, the combined sources of inlet air forming an inlet plenum fluid stream, the treatment plenum comprising a photocatalytic oxidation (PCO) device substantially enshrouding an ultraviolet (UV) light device, the PCO device activated by the UV light device when energized, wherein the UV light device produces an ultraviolet germicidal irradiation (UVGI) effect and causes the production of at least one reactive oxygenation species (ROS) for introduction into the mechanically-filtered fluid stream to produce a treated fluid stream that is subsequently returned to the evaporator air space.

[0017] Variations on this embodiment include: a recirculation port through which at least a portion of the treated fluid stream is recirculated prior to its return to the evaporator air space; a mechanical filtration device for filtering substantially all of the inlet plenum fluid stream; an air-motive device capable of producing a positive treated fluid stream pressure within the evaporator air space; production of at least two ROS, wherein at least one of the ROS is hydrogen peroxide; a volumetric flow rate of the evaporator air entering the inlet plenum is less than the volumetric flow rate of the treated fluid stream entering the evaporator air space; and an LED light device capable of ultraviolet light generation.

[0018] Another embodiment provides an apparatus for inhibiting the growth of microbiological organisms in a commercial icemaker or refrigeration device, the apparatus comprising: an inlet port and an outlet port having a fluid path therebetween, and an air-motive device effecting the flow of air from the inlet port to the outlet port, both ports in fluid communication with the evaporator area air space of an icemaker or refrigeration device, a pretreatment fluid stream comprising the inlet port air stream; a mechanical filtration device and a photocatalytic oxidation (PCO) device through which substantially all of the pretreatment fluid stream must pass, the PCO device substantially enshrouding an ultraviolet (UV) light device, the PCO device activated by the energized UV light device, wherein the UV light device produces an ultraviolet germicidal irradiation (UVGI) effect and causes the production of at least one reactive oxygenation species (ROS) for introduction into the pretreatment fluid stream, resulting in a treated fluid stream that is moved to the outlet port by the air-motive device; and a recirculation port through which at least a portion of the treated fluid stream is recirculated to the mechanical filtration device or the PCO device.

[0019] Variations on this embodiment include: a fresh-air port allowing the entry into the apparatus fluid path of air that is ambient to the exterior of the apparatus housing, the pretreatment fluid stream further comprising the fresh-air port fluid stream; an air-motive device \capable of producing a positive treated fluid stream pressure within the evaporator air space; production of at least two ROS, wherein one of the ROS is hydrogen peroxide; a configuration wherein volumetric flow rate of the evaporator air drawn from the evaporator air space by the apparatus is less than the volumetric flow rate of the treated fluid stream entering the evaporator air space from the apparatus; and an LED light device capable of ultraviolet light generation.

[0020] Yet another embodiment the invention teaches a method for inhibiting the growth of microbiological organisms in a commercial icemaker or refrigeration device, the method steps comprising: removing a portion of the air from the evaporator air space of an icemaker or refrigeration device and mixing the air with air ambient to the exterior of the icemaker or refrigeration device; treating the filtered air with an ultraviolet (UV) light device and a photocatalytic oxidation (PCO) media activated by the UV light; and returning the treated air under pressure to the evaporator air space to maintain a positive pressure therein.

[0021] Variations on this method include: causing the production of reactive oxygen species (ROS) for treating microbes present in the evaporator air space; causing the production of reactive oxygen species (ROS) for treating microbes present in the evaporator air space, wherein the ROS is hydroxyl radicals or hydrogen peroxide; recirculating a portion of the treated air such that the recirculated portion is treated by the UV light device and PCO media to increase the residence time of the treated air; recirculating a portion of the treated air such that the recirculated portion is treated by the UV light device and PCO media to control the level of reactive oxygen species present in the treated air; providing a UV light of sufficient intensity to substantially illuminate the depth of the PCO material; and providing turbulent flow of filtered air through the PCO media and over the UV light device to increase the amount of air contact with the PCO media and UV light device surface.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0022] The present invention will be more fully understood by reference to the following detailed description of the preferred embodiments of the present invention when read in conjunction with the accompanying drawings, wherein:

[0023] FIG. **1** is a perspective view of an embodiment of the biological growth inhibiting apparatus disclosed herein;

[0024] FIG. **2** is a side view of the embodiment highlighting the PCO media support grid and its orientation within the apparatus;

[0025] FIG. **3** is a perspective view of the embodiment with covers removed to reveal inner components and plenum structure;

[0026] FIG. **4** is a bottom-up perspective view of the embodiment to highlight additional aspects of its structure;

[0027] FIG. **5** is a ghosted perspective view of an additional embodiment of the biological growth inhibiting apparatus disclosed herein;

[0028] FIG. **6** is an embodiment of the control circuitry schematic for the apparatus; and

[0029] FIG. **7** is a depiction of an icemaker system incorporating an apparatus embodiment.

[0030] The above figures are provided for the purpose of illustration and description only, and are not intended to define the limits of the disclosed invention. Use of the same reference number in multiple figures is intended to designate the same or similar parts. Furthermore, when the terms "top," "bottom," "first," "second," "upper," "lower," "height," "width," "length," "end," "side," "horizontal," "vertical," and similar terms are used herein, it should be understood that these terms have reference only to the structure shown in the drawing and are utilized only to facilitate describing the particular embodiment. The extension of the figures with respect to number, position, relationship, and dimensions of the parts to form the preferred embodiment will be explained or will be within the skill of the art after the following teachings of the present invention have been read and understood.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Fundamentally, photocatalysis involves light energy activating a catalytic substrate, which then catalyzes oxidation-reduction (redox) reactions with adsorbed reactants. An appropriate semiconductor material (often metal oxides such as titania, TiO2) is often used as the catalyst surface, and oxygen and water molecules present in the air usually play a role in the reactions. PCO therefore can occur either in liquid water or in gaseous air. The type of photocatalysis relevant to this discussion is referred to as "heterogeneous" (gas/solid), as gas-phase oxygen and water vapor in air are involved in reactions on the solid catalyst surface. The light-activated redox reactions produce highly-reactive intermediate species containing oxygen. Microbiological and other types of organic contaminants carried in the air can be oxidized either by reaction directly on the catalyst surface or by subsequent reaction with the reactive oxygen species (ROS) produced by surface reactions. It is this oxidation of organic material that is referred to as "photocatalytic oxidation" (PCO).

[0032] FIG. **1** depicts a perspective view of an embodiment of the biological-growth inhibiting apparatus (**100**) described herein. The apparatus treats the air circulating within the ice-making zone of an ice machine, thereby inhibiting microbiological organism growth. In addition, fresh room air is drawn into the apparatus where it is filtered and likewise treated and combined with recirculated air from the ice machine to create a positive air pressure in the evaporator enclosure and the ice storage bin, thereby minimizing the entry of untreated external air from entering these areas. The apparatus utilizes broad-spectrum technology to destroy microbiological organism growth—including mold, mildew and fungus—that is commonly found on surfaces in commercial icemakers. This broad-spectrum treatment technology consists of a combination of particulate filtration, PCO and ultraviolet germicidal irradiation (UVGI). The combination of PCO and UVGI technologies cause the production of hydroxyl radicals and other reactive oxygen species (ROS), for example hydrogen peroxide and ozone, which serve to reduce overall biological contamination. Features are also incorporated to increase the residence time of the air within the treatment chamber thereby increasing the operating efficiency of the apparatus.

[0033] The apparatus (**100**) is contained within an enclosure (**102**) that serves to orient the internal components, creates an air flow plenum for the direction of air within the apparatus, and serves as a means for mounting the apparatus to an ice machine, commercial cooler or refrigeration device, or nearby structure. The enclosure (**102**) is preferably rigid and may be made from any suitable rigid or semi-rigid material (for example, metal, plastic, or the like), and includes removable panels to allow periodic maintenance and repairs to be performed on the components therein. In the present embodiment the enclosure (**102**) is crafted from **304** stainless steel or metal similar or identical to that used with the ice machine or cooler structure to which it may be attached. Nonetheless, one of ordinary skill will appreciate that any rigid or semi-rigid material may be utilized depending on the mounting and operating environment requirements. Also, if plastic is chosen, it is desirable to take steps to limit the sensitivity of the plastic to the UV light and ROS, for example, by coating or lining the interior of the UV chamber or the entire apparatus interior with metallic tape or similar UV/ROS resistant coating, otherwise the lifespan of the enclosure might be adversely impacted.

[0034] The apparatus (**100**) includes an input duct connected to an inlet fitting (**104**) and an output duct connected to an outlet fitting (**106**), through which air travels between the apparatus and the connected icemaker or commercial refrigeration device. The fittings (**104** and **106**) include barbed features for retention of a flexible hose or pipe. Also shown are a vent port (**108**), which serves as a vent for the enclosed electronics, and an indicator light (**110**), which illuminates when the control circuitry is operating. As the apparatus operates, heat is produced by the electronics therein. The vent port (**108**) allows this heat to escape thereby minimizing the adverse impact heat might have on the lifespan of the control circuitry. Also shown in its removed state is a particulate filter (**112**) for mechanical filtration of the air stream, which is removable by the operator for periodic maintenance. In the present embodiment the particulate filtration (the first treatment stage) utilizes high efficiency diffusion media or equivalent with a bonded to a wire or plastic frame support and a gradient density with an approximate **10** micron particulate removal rating. This filter is readily replaceable during periodic maintenance. One of ordinary skill will appreciate that other particulate filter media may be utilized depending on installation and cost requirements. For example, other embodiments may utilize woven or nonwoven polyester, polyolefin, or aluminum or other metal mesh, or the like, which are capable of the same or differing filtering effect. For example, filter media having a smaller micron rating may be desired in order to block smaller particulate matter that may be present in a certain environment. Such smaller-rated media, however, will be subject to more frequent replacement due to the increased amount of trapped particulate matter. One of ordinary skill will understand that the level of particulate removal will impact the frequency of filter servicing, and will select the filtering media accordingly.

[0035] FIG. **2** depicts a perspective view of the embodiment with the outer covers removed to reveal the inner components and plenum structure. On the outer surface of the apparatus is a fresh-air port (**202**) through which ambient air from outside the icemaker/commercial cooler evaporator space (untreated air) may enter the apparatus and mix in the input plenum (**204**) with the air drawn from the icemaker/cooler interior. The fresh-air port (**202**) in the present embodiment comprises louvers, which provide somewhat of a restrictive effect on the amount of ambient air that is drawn into the apparatus. Accordingly, it is possible to adjust the amount of additional air introduced into the apparatus depending on the size of these openings in the fresh-air port (**202**) cover. The louvers (or restrictors) also serve to pre-filter large debris or insects that might be present in the ambient air; however, this is not the primary purpose for this feature. The fresh air entering the fresh-air port (**202**) is combined with the input duct air (from the icemaker/refrigeration device evaporator air space) within the inlet plenum (**204**). This combined air is considered the inlet plenum air fluid stream or the pretreatment fluid stream. Not visible in this figure (but visible in subsequent figures) is the mechanical filtration device (**112**), which separates the inlet plenum (**204**) from the treatment plenum (**206**). Substantially all of the pretreatment fluid stream passes through the mechanical filtration device (**112**) and into the treatment plenum (**206**), where it must then pass through the PCO media (**210**) for subsequent treatment.

[0036] The PCO media support grid (**208**) and its orientation within the apparatus is visible in this drawing. As depicted, this flexible mesh grid comprised of plastic is utilized to provide support for the PCO media (**210**) to enable the PCO media to be shaped to essentially surround a UV lamp (not shown in this figure, but visible in subsequent figures) such that the UV lamp is not directly visible with the outer apparatus covers removed. In this configuration the PCO media (**210**) and support grid (**208**) form a "U" shape that substantially enshrouds the UV lamp. This configuration allows for ease of removal of the PCO support grid (**208**) and media (**210**) for periodic servicing.

[0037] FIG. **3** depicts a perspective view of the apparatus with the PCO support grid (**208**) and media (**210**) removed to show the underlying components. Again, the particulate filter (**112**), or mechanical filtration device is visible in its installed position, separating the input plenum (**204**) from the treatment plenum (**206**). The treatment plenum (**206**) includes a UV lamp (**308**) and an appropriate socket receptacle (**310**) for support and operation thereof. Irradiation of any surviving airborne microbes by the UV lamp, causing cell destruction, occurs in this third stage of air treatment. This lamp also serves the functions of activating the PCO media for the formation of ROS, and generating additional residual ROS (for example, ozone) that is injected into the icemaker evaporator air space. In this embodiment the UV lamp (**308**) comprises two main tubes joined near the top by a crossover port. The UV lamp (**308**) in this configuration is more compact than a conventional straight single-tube UV lamp of comparable surface area.

[0038] The UV germicidal lamp, as it is generally known, emits light energy in the UV wavelengths most effective for the production of germicidal effect and production of ozone. This UV wavelength is determined in part by the density or makeup of the glass tube that comprises the outer structure of the UV lamp (**308**). Different glass materials may be fused together to allow a single UV lamp device to produce multiple UV wavelengths. For example, in the present embodiment the UV lamp (**308**) comprises a segment (**318**) that emits UV at a wavelength of less than 240 nm. At these wavelengths, substantial ozone is produced during operation. The remaining segment of the UV lamp (**320**) emits UV at a different wavelength intended to increase the effectiveness of biological contaminant destruction. Thus, it is possible to achieve a predetermined residual level of ozone within the evaporator air space by selecting a UV lamp (**308**) with the desired glass tube wavelength characteristics.

[0039] Above the UV lamp is the control circuitry, comprising a centrifugal fan/blower device (**212**) and a ballast device (**214**). The ballast device (**214**) provides power the UV lamp (**308**) to effect operation thereof. The centrifugal blower air-motive device (**212**) provides the primary force to effect the flow of air through the apparatus. Also visible in the present embodiment is a UV reflective material (**316**) on the walls of the treatment plenum (**206**). This material (**316**) reflects more of the UV light emitted from the lamp back into the treatment plenum relative to the bare stainless steel walls of the plenum, thereby increasing the germicidal effect of the apparatus. In the present embodiment this reflective material (**316**) is aluminum tape. However, one of ordinary skill will appreciate that other metalized films or coatings that enhance the reflection of UV light may be utilized and are within the scope of the present invention. This material (**316**) may also be utilized to protect the plenum walls from the negative effects of generated ROS as well, if such protection is considered necessary.

[0040] The present embodiment utilizes a 12VDC centrifugal blower or equivalent as a recirculation blower (**212**), which is designed to draw the air through the treatment stages. Although the blower (**212**) in this embodiment has an input power rating of 2.4-4 watts, an air flow CFM of 8.94-15.90, and a max air pressure of 6.33-12.00 mm H2O, other ratings may be required due to the apparatus and icemaker operating criteria, such as the overall volume of the icemaker and the available voltage supply. It is within the skill of one of ordinary skill in the art to determine the necessary operating criteria for selection of an appropriate blower device.

[0041] Referring again to FIGS. **2** through **4**, after removing particulate matter from the air, the filtered air in the apparatus continues to the second treatment stage that includes the PCO media (**210**) for surface mediated oxidation-reduction (REDOX) reactions. The light from the UV lamp striking the surface of the PCO media (**210**) causes energetic activation of the PCO media, enabling the reactions with the air that produce ROS. ROS present near the surface of the media cause destruction of airborne microbes.

[0042] The PCO media (**210**) in the present embodiment is a relatively thin mat comprised of layers of randomly enmeshed, woven quartz silica glass fiber material strands that further comprise a titanium dioxide coating. In other embodiments the media may be a matte web made up of glass, cellulose or suitable synthetic polymer or polyolefin felt, or some combination of these materials. In the present embodiment the media (**210**) is approximately 20 mm thick and is wrapped substantially axially around the UV lamp (**308**), and is oriented within the enclosure (**102**) such that substantially all of the filtered air is drawn through the weave during operation of the apparatus. Because radiation strength decreases exponentially with distance from the source, the PCO media (**210**) is positioned as reasonably close to the UV lamp (**308**) as possible to ensure efficient use of the emitted UV light without contacting the UV lamp (**308**) surface. Curving the PCO media around the lamp—at a short distance from the light-emitting lamp surface—greatly increases exposure of the media to UV light of an appropriate intensity, as opposed to merely exposing a single flat surface of PCO media on one side of the UV lamp. This curved configuration activates a larger media surface area for oxidative reactions and optimizes efficient use of the electric power being fed to the device. Thus, the PCO media transmits UV light throughout the woven fibers, providing the equivalent of approximately 6500 sq. ft. of effective surface area in the present embodiment to produce ROS. A minimal additional particulate filtration effect is also observed given that the air must pass through the enmeshed strands of the PCO media (**210**) during treatment.

[0043] In additional detail, the basic mechanism of PCO as used for air treatment is as follows: Light strikes the surface of the catalyst with sufficient energy to excite electrons from the valence band to the conduction band so that they can migrate. The ability of the light to supply this "band-gap energy" depends upon the energy carried by a photon, which is determined by the wavelength of the light. (The shorter the wavelength, the higher the wave frequency and the higher the photon energy.) Ultraviolet light (UV) has the appropriate wavelength (from 185 to 400 nm) to supply the band-gap energy of a catalyst such as TiO2. Thus, a UV lamp is used in the air-treatment device described herein. The UV light shining on the surface of the catalytic media "activates" the catalyst for redox reactions. The catalytic media, or "PCO media," is a substrate coated with titania, providing a surface area upon which PCO occurs.

[0044] Electrons promoted to the conduction band create paired electron-hole charge carriers at the surface of the catalytic media. It is then these charge carriers (either electrons or holes) that perform electron exchange (redox) with oxygen and water molecules at the media surface. Regardless of the chemical pathway chosen for the photocatalytic production of a given ROS, H2O and O2 are converted to various ROS, for example hydroxyl radicals, hydrogen peroxide, ozone, and others. Many of these species are so reactive that they exist for a very short time before finding something to react with, making their direct measurement a significant challenge (most hydroxyl radicals have a half-life on the order of a nanosecond). The presence of these highly reactive species is best detected by the oxidative effects they have on other materials. Some ROS, however, such as ozone and hydrogen peroxide, will survive for an extended period of time, and can be carried downstream in the air that has been treated by contact with the catalyst.

[0045] ROS produced by PCO degrades microbes suspended in the air within the ice-making zone of an ice machine. The chemical products of reactions between ROS and any organic material are primarily CO2 and H2O, both of which are harmless. PCO is therefore different from the use of most chemical disinfectants, which remain in the environment. No significant amount of ROS escapes the ice machine into the environment, and only a very low, non-hazardous concentration of ROS is present at the opening of the ice bin where operators can come into contact with it. None of the ROS remain in the environment long-term, and once the ROS has done its job, the byproducts are harmless carbon dioxide and water. In addition, PCO has a built-in ability to limit the concentration of ozone. Although ozone is a ROS product, some of the many redox reactions that take place in PCO also destroy ozone. Because of chemical reaction kinetics, the higher the concentration of ozone present, the more those reactions will work to convert that ozone to oxygen. To state differently, if the ozone concentration were to become extremely low, kinetics would naturally allow production of more ozone. Therefore, PCO essentially has a self-regulating feature to limit ozone.

[0046] Although PCO is a scientifically valid process that has been clearly shown to be effective in degrading microbial growth, the apparently ethereal nature of some ROS makes proving or disproving their presence in specific photocatalytic air purification devices virtually unattainable. Perhaps for this reason, others have promoted air-cleaning devices with overly simple catalyst media, not designed in such a way that effective PCO of microbes could ever possibly occur. The device presented here, by contrast, has a uniquely designed reaction chamber and treatment process that ensures significant and demonstrable PCO activity. The design treats the evaporator air space in a typical commercial ice machine, which contains particularly problematic microbes, has a high humidity level and relatively small air volume, utilizes susceptible materials of construction, has an unusual operator interface for accessing the enclosed and contaminant-laden environment with a multitude of crevices in which microbes hide.

[0047] It should also be noted that PCO anti-microbial air treatment has several important design qualifications, many of which are ignored by existing ice-machine air-treatment designs. The following factors must preferably be incorporated into a PCO design to ensure that significant PCO activity will occur:

[0048] UV Light Intensity—The UV source must be sufficiently powerful, and the catalyst sufficiently close to the source, for the catalyst to be activated. The light intensity drops exponentially as the distance from the source increases. The catalyst must therefore be as close as physically possible to the UV lamp and still allow air to pass. The necessary irradiance level at the catalyst is estimated to be in the vicinity of approximately 8 mW/cm2. Also inherent in the UV intensity requirement is the fact that UV lamp failure (which occurs in a relatively predictable time span) must be followed by lamp replacement by the user. Device design thus must incorporate convenient lamp replacement, or after some time of usage there will no longer be sufficient light intensity for effective treatment.

[0049] Spatial Considerations—The practical requirements of placing a treatment device adjacent to an ice machine or other such commercial refrigeration device mean that the device must be very compact. Effective air treatment components must be contained within a tiny compartment. In addition, the air volume of the ice machine must be considered. For effective treatment, all air in that volume must be treated repeatedly, therefore requiring significant turnover of the air with adequate airflow rates. If only a portion of the ice machine air is treated very slowly, then stray microbes have sufficient time to adhere to the ice machine surfaces and proliferate.

[0050] Surface Area—PCO is completely dependent upon the catalyst surface area available to produce reactions. A very large PCO-reactive surface is required for any significant antimicrobial effect. The catalyst surface must be sufficiently irradiated to be effective, and therefore all available surface must be sufficiently close to the UV source to ensure this occurs. This problem is resolved by the proper selection of media, packing a large surface area into a small space. It is also important that the media allow transmission of light throughout the depth of the material for maximum utility.

[0051] Air-Catalyst Contact—It is not sufficient for the treated air to pass in the vicinity of the catalyst surface; it must come in intimate contact with the surface. As with most designs of chemical reactors, turbulent flow with rapid mixing, rather than slow laminar flow, is much better for providing both close surface contact and movement of reactants to/from the surface. The best air flow design and choice of catalyst media will involve the flow of all treated air directly through the interwoven fibers of the media, placing all air in close contact with the catalyst. This configuration however requires that there be a very limited drop in pressure as the air passes through the media; too much resistance to flow will result in insufficient flow. This affects both the selection of the catalyst media and the decision to either filter or not filter the air prior to PCO treatment. With the use of PCO media that the air flows through with intimate contact, pre-filtration is required otherwise airborne particles (common in the commercial locations where ice machines are used) will most likely clog the PCO media and air treatment will cease. Filtration is therefore integral to a favored treatment design that is specific to the needs of commercial ice machine users. Also, a crucial feature of the device design is the relative ease with which the user can replace this pre-filter.

[0052] Residence Time—In order for sufficiently large amounts of ROS to be produced, treated air preferably must have extended contact time with the catalyst. With air flowing rapidly through a small device enclosure, the preferred way to achieve this is by recirculating the air repeatedly through the PCO media. With the device discussed here, air is recirculated both externally and internally to the treatment chamber.

[0053] FIG. **4** depicts a bottom-up perspective view of the embodiment, highlighting additional aspects of the apparatus as visible from within the treatment plenum. As depicted, the input to the centrifugal blower device (**212**) is positioned near the top end of the UV lamp (**308**) in the top surface of the treatment plenum (**206**). One of ordinary skill will appreciate that during operation a centrifugal blower device produces more of a positive air pressure at the output duct as opposed to an axial flow fan, which in comparison is essentially incapable of production of a positive air pressure output due to the open fan blade design. Also visible in the figure is a treated-air recirculation port (**402**), which allows for the recirculation of a portion of the treated air from the blower (**212**) outlet into the treatment plenum (**206**) where it is treated yet again. Immediately recirculating a portion of the treated air provides the benefit of increasing the residence time, thereby increasing the overall PCO effect of the apparatus.

[0054] In the present embodiment the centrifugal blower (**212**) runs at a fixed speed during normal operation, thereby moving air at a relatively constant rate. In another embodiment the blower (**212**) runs at a variable speed based upon the ROS and/or biological contaminant levels measured within the icemaker/cooler. During operation the blower creates a positive pressure at the output duct and, consequently, creates a relative negative pressure in the treatment (**206**) and input (**204**) plenums. This negative pressure draws ambient air through the fresh-air port (**202**) and draws recirculated air (from the evaporator air space of the icemaker/cooler interior) through the input duct. The fresh-air and recirculated air mix within the input plenum (**204**), and this mixture is subsequently filtered from particulates by the particulate filter device (**112**) as the mixture is drawn into the treatment plenum (**206**). In the treatment plenum (**206**) the filtered air passes through the support grid and PCO media (**208**), over the surface of the UV lamp (**208**), and into the centrifugal blower (**212**) inlet opening, effectively exiting the treatment plenum. A portion of the treated air (approximately 25% in the present embodiment) is subsequently fed back from the blower through the treated-air recirculation port (**402**) to increase the residence time, while the remaining bulk of the treated air is pushed under pressure through the output duct and into the icemaker/cooler evaporator area. Thus, a positive pressure is maintained within the evaporator area because the addition of the fresh air causes the output air volume of the apparatus to exceed the simple input air volume that is drawn from the icemaker/cooler evaporator area. This positive pressure and relatively high volumetric flow rate creates turbulence within the evaporator air space to allow the treated air to reach a greater portion of the evaporator space than other units that rely on low to no pressure and/or laminar air flow.

[0055] Tests were recently performed on the apparatus in the present embodiment to determine its effectiveness in removing microbiological organisms under extreme situations. In all tests it was shown that there was at least a 99.9% reduction:

[0056] Bacteria: Log Reduction 5.9—Percent Reduction 99.9999% (geometric mean)

[0057] Fungus: Log Reduction 3.4—Percent Reduction 99.96% (geometric mean)

Accordingly, it has been independently verified by a testing laboratory specializing in the evaluation of anti-microbial devices and compared using two commercial icemakers, one with the disclosed apparatus and one without.

[0058] Other embodiments may include yet additional features. For example, in another embodiment a vacuum switch is included in the enclosure on the downstream side of the particulate filter (**112**) to measure the vacuum within the enclosure on the intake side of the operating blower (**212**). If the filter (**212**) becomes obstructed, the reduced airflow through the filter will result in increased vacuum within the treatment plenum (**206**). The vacuum switch may thus indicate when the filter media (**112**) requires replacement, and may halt the blower or provide a visual or audible indicator to alert an operator to the condition needing attention.

[0059] A vacuum break may also be utilized to prevent collapse of the enclosure (**102**) due to excessive vacuum or to prevent the ceasing of air treatment due to an obstructed mechanical filter device. For example, in another embodiment a vacuum break is installed in the bottom of the enclosure (**102**) and mated with a port into the evaporator area of the icemaker upon which it is installed. When excessive vacuum occurs and the vacuum break trips, air from the evaporator area is subsequently drawn into the enclosure (**102**), effectively bypassing the obstructed filter (**104**). Partial treatment of the air may still occur, albeit without particulate filtration occurring. In yet another embodiment, the vacuum break is entirely contained within the apparatus (**100**) such that it provides a path for air around the air filter (**112**) frame or mounting flange.

[0060] FIG. **5** depicts another embodiment of the apparatus. The UV lamp (**502**) in this embodiment is a single tube lamp that is substantially enshrouded by PCO media (**504**) such that air entering the treatment plenum (**520**) must pass through the PCO media (**504**) on the way to the outlet port (**508**). Control circuitry (**506**) powers the UV lamp (**502**) and a centrifugal blower device (**512**). This lamp (**502**), as with the previous embodiment, emits UV light to activate the PCO media (**504**) and cause the formation of ROS (for example, hydrogen peroxide). The UV lamp (**502**) also provides ultraviolet germicidal irradiation (UVGI) to inactivate airborne organisms that might survive the PCO stage and generates an additional small amount of ROS (ozone) as a residual that is circulated in the air and is injected into the icemaker evaporator air space. In this embodiment, the UV lamp (**502**) is an Atlantic® UV lamp or equivalent, with the following specifications: 10W 212 mm long, and approximately 254 nm wavelength. However, one of ordinary skill will appreciate that other UV lamps having similar characteristics may be utilized and may be tailored to different physical design limitations and power specifications, and are within the scope of the claims. For example, LED UV lamps may be selected for low-power/voltage applications. The ballast device (**506**) powers the UV lamp (**502**) but is not exposed to the UV light or the ROS, which would have a negative impact on the lifetime of the electronics and plastics associated therewith.

[0061] After passing through the previous three treatment stages, the treated air is returned to the icemaker evaporator zone via the discharge plenum (**508**). A portion of the air within the evaporator zone of the icemaker is then recirculated by the apparatus, greatly increasing the effectiveness of the PCO treatment of the air. In the present embodiment a recirculation port (**522**) is utilized to allow a portion of the treated air from the blower (**512**) to return to the inlet plenum (**518**) where it combines with the inlet plenum air fluid stream. The residual ROS in the recirculated air acts as a "bio-stat" for the first treatment stage particulate filtration media (**510**). Recirculation of the interior air also prevents excessive buildup of ROS (for example, ozone) by its destruction due to contact with the UV illuminated PCO media (**504**). By destroying a portion of the ozone present in the recirculated air, the levels of ozone within the icemaker/cooler evaporator section can be maintained at a level that is safe for the workers accessing the machine and the components within the device. While the present embodiment includes a recirculation port (**522**) in the inlet plenum (**518**), other embodiments place the port in the treatment plenum (**520**) where the recirculated portion of the treatment fluid stream may bypass the particulate filter (**510**) in order to increase the "bio-stat" effect of the residual ozone on the PCO media (**504**).

[0062] In another embodiment, the input plenum area (**518**) upstream of the particulate filtration stage includes an adjustable fresh air port (**514**) that allows the user to adjust the amount of fresh air that is allowed into the apparatus (**500**) to mix with the air fluid stream entering the apparatus through the inlet port (**516**). The addition of the fresh air introduced into the Icemaker from the outside with the air taken from the evaporator air space allows a positive air pressure to be established within the evaporator air space once this expanded volume is returned. This increase in air pressure in the evaporator compartment prevents the influx of non-treated air into the evaporator space when the ice storage bin is accessed. In certain instances wherein the ambient air contains unreasonably high quantities of contaminants, it is possible to close off the fresh-air port (**514**) entirely. For example, in a bakery setting there may be high levels of yeast in the atmosphere, the introduction of which (into the air stream) might reduce the effectiveness of the apparatus in removing biological contaminants. During times of high yeast levels, it is therefore possible to close off the fresh-air port to prevent introduction of airborne yeast into the evaporator area. When the yeast levels drop, it is then possible to reopen the fresh-air port to restore the operation to normal.

[0063] FIG. **6** depicts a schematic diagram of the control circuitry for an embodiment of the apparatus. As shown, an AC to DC converter device (**602**) is used to accept AC power from a standard outlet (**604**) and convert the power to a DC voltage and current suitable for the remaining components. The DC power is supplied to the centrifugal blower (**606**) and to a ballast device (**608**) capable of energizing the UV lamp (**610**) during operation. When energized, an indicator LED (**612**) is also provided to give an operator an indication that the apparatus is operational and also indicating the presence within the device of hazardous UV light and ozone.

[0064] FIG. **7** depicts a typical installation of the apparatus on a commercial icemaker. As shown, the apparatus (**100**) is mounted on the wall next to the icemaker (**700**), where the inlet (**104**) and outlet (**106**) are plumbed directly to the evaporator area (**702**). In another embodiment, the apparatus is installed mounted directly on the side or top of the evaporator area, such as for clearance purposes or for aesthetic reasons. Two plumbed hoses or lines for the apparatus inlet (**104**) and outlet (**106**) air ports must be connected by the installer in the top or side of the icemaker, relative to the installation location. With the apparatus installed on the outside of the icemaker, the icemaker internal components are not exposed to the UV light. Moreover, due to the previously described internal destruction mechanism of ROS, the icemaker components will be exposed to levels of ROS that are well below tolerable limits.

[0065] In another embodiment, the apparatus monitors and controls the ROS concentration. This embodiment utilizes an ROS sensor chip and switch circuit that is mounted in the plenum, in the incoming airstream prior to the particulate filter (**204**). The sensor chip monitors the ROS levels in the incoming air and, if the ROS exceeds a certain level for an extended period of time, the control circuit turns off the apparatus until the ROS level drops to the desired level of ROS.

[0066] In another embodiment, the apparatus is incorporated as an integral component of the icemaker. For example, the apparatus enclosure may be permanently attached to the icemaker housing with a dedicated inlet and outlet plenum to allow for air to flow from the evaporator/ice storage area through the apparatus and return. In yet another embodiment the internal air circulation fans for the icemaker may be utilized to also move air through the apparatus, precluding the need for the recirculation blower motor within the apparatus. The integral apparatus may be mounted inside of the icemaker housing such that it is not visibly perceivable without removal of access panels intended to allow for maintenance of the icemaker components.

[0067] Although the apparatus has been described herein as an embodiment for use with commercial icemakers, its use and benefits extend to any device that uses refrigeration for cooling, such as commercial walk-in and reach-in coolers. In these embodiments, the evaporator area air is, once again, directed into the apparatus for treatment as described above. The treated air is returned to the evaporator area and circulated throughout the refrigeration device, where it is subsequently recirculated through the apparatus for continued treatment.

[0068] The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive. Accordingly, the scope of the invention is established by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. Further, the recitation of method steps does not denote a particular sequence for execution of the steps. Such method steps may therefore be performed in a sequence other than that recited unless the particular claim expressly states otherwise.

We claim:

1. An apparatus for inhibiting the growth of microbiological organisms in a commercial icemaker or refrigeration device, the apparatus comprising:

an inlet plenum in fluid communication with a treatment plenum, the inlet plenum accepting air from the evaporator air space of an icemaker or refrigeration device, the inlet plenum further accepting ambient air from the air space surrounding the apparatus, the combined sources of inlet air forming an inlet plenum fluid stream, the treatment plenum comprising a photocatalytic oxidation (PCO) device substantially enshrouding an ultraviolet (UV) light device, the PCO device activated by the UV light device when energized, wherein the UV light device produces an ultraviolet germicidal irradiation (UVGI) effect and causes the production of at least one reactive oxygenation species (ROS) for introduction into the mechanically-filtered fluid stream to produce a treated fluid stream that is subsequently returned to the evaporator air space.

2. The apparatus of claim **1**, the apparatus further comprising:

a recirculation port in the inlet plenum or in the treatment plenum through which at least a portion of the treated fluid stream is recirculated prior to its return to the evaporator air space.

3. The apparatus of claim **1**, the apparatus further comprising:

a mechanical filtration device separating the inlet plenum from the treatment plenum, wherein substantially all of the inlet plenum fluid stream must pass through the mechanical filtration device.

4. The apparatus of claim **1**, the apparatus further comprising:

an air-motive device capable of producing a positive treated fluid stream pressure within the evaporator air space.

5. The apparatus of claim **1** wherein at least two ROS are produced, wherein at least one of the ROS is hydrogen peroxide.

6. The apparatus of claim **1** wherein the volumetric flow rate of the evaporator air entering the inlet plenum is less than the volumetric flow rate of the treated fluid stream entering the evaporator air space.

7. The apparatus of claim **1**, the UV light device comprising an LED light device capable of ultraviolet light generation.

8. An apparatus for inhibiting the growth of microbiological organisms in a commercial icemaker or refrigeration device, the apparatus comprising:

an inlet port and an outlet port having a fluid path therebetween, and an air-motive device effecting the flow of air from the inlet port to the outlet port, both ports in fluid communication with the evaporator area air space of an icemaker or refrigeration device, a pretreatment fluid stream comprising the inlet port air stream;

a mechanical filtration device and a photocatalytic oxidation (PCO) device through which substantially all of the pretreatment fluid stream must pass, the PCO device substantially enshrouding an ultraviolet (UV) light device, the PCO device activated by the energized UV light device, wherein the UV light device produces an ultraviolet germicidal irradiation (UVGI) effect and causes the production of at least one reactive oxygenation species (ROS) for introduction into the pretreatment fluid stream, resulting in a treated fluid stream that is moved to the outlet port by the air-motive device; and

a recirculation port through which at least a portion of the treated fluid stream is recirculated to the mechanical filtration device or the PCO device.

9. The apparatus of claim **8**, the apparatus further comprising:

a fresh-air port allowing the entry into the apparatus fluid path of air that is ambient to the exterior of the apparatus housing, the pretreatment fluid stream further comprising the fresh-air port fluid stream.

10. The apparatus of claim **8** wherein the air-motive device is capable of producing a positive treated fluid stream pressure within the evaporator air space.

11. The apparatus of claim **8** wherein at least two ROS are produced, wherein one of the ROS is hydrogen peroxide.

12. The apparatus of claim **8** wherein the volumetric flow rate of the evaporator air drawn from the evaporator air space by the apparatus is less than the volumetric flow rate of the treated fluid stream entering the evaporator air space from the apparatus.

13. The apparatus of claim **8**, the UV light device comprising an LED light device capable of ultraviolet light generation.

14. A method for inhibiting the growth of microbiological organisms in a commercial icemaker or refrigeration device, the method steps comprising:

removing a portion of the air from the evaporator air space of an icemaker or refrigeration device and mixing the air with air ambient to the exterior of the icemaker or refrigeration device;

treating the filtered air with an ultraviolet (UV) light device and a photocatalytic oxidation (PCO) media activated by the UV light; and

returning the treated air under pressure to the evaporator air space to maintain a positive pressure therein.

15. The method of claim **14**, the method steps further comprising:

causing the production of reactive oxygen species (ROS) for treating microbes present in the evaporator air space.

16. The method of claim **14**, the method steps further comprising:

causing the production of reactive oxygen species (ROS) for treating microbes present in the evaporator air space, wherein the ROS is hydroxyl radicals or hydrogen peroxide.

17. The method of claim **14**, the method steps further comprising:

recirculating a portion of the treated air such that the recirculated portion is treated by the UV light device and PCO media to increase the residence time of the treated air.

18. The method of claim **14**, the method steps further comprising:

recirculating a portion of the treated air such that the recirculated portion is treated by the UV light device and PCO media to control the level of reactive oxygen species present in the treated air.

19. The method of claim **14**, the method steps further comprising:

providing a UV light of sufficient intensity to substantially illuminate the depth of the PCO material.

20. The method of claim **14**, the method steps further comprising:

providing turbulent flow of filtered air through the PCO media and over the UV light device to increase the amount of air contact with the PCO media and UV light device surface.

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