OZONE LAUNDRY SYSTEMS

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Appl. No.: 13/072,132
Filed: Mar. 25, 2011

Related U.S. Application Data
Division of application No. 12/119,235, filed on May 12, 2008.
Provisional application No. 60/917,560, filed on May 11, 2007, provisional application No. 60/917,566, filed on May 11, 2007.

Publication Classification
Int. Cl.
D06F 1/20 (2006.01)
D06F 37/00 (2006.01)

ABSTRACT
Ozone laundry systems include one system, a tunnel washer system that generates ozone and dissolves the ozone in water at various stages of the tunnel washer, such as with a Venturi injector. The ozonated water may be stored and recirculated/re-ozonated to ensure that a desired level of dissolved ozone is present in any water delivered to the various zones of the tunnel washer. The ozonated water provides maximum cleaning efficiency and effectiveness at cooler water temperatures, saving water and energy costs. In some systems, controlled safe application of gaseous and/or dissolved ozone may be made to laundry in a washer. Ozone levels may be monitored and precisely controlled. The application of ozone using some embodiments allows the ozone to treat materials and articles of clothing such as jeans to achieve a desired look and feel, such as an appearance of having been worn.
FIG. 8
OZONE LAUNDRY SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional application of U.S. patent application Ser. No. 12/119,235 filed May 12, 2008 which claims the benefit of U.S. Provisional Application No. 60/917,560 filed May 11, 2007, and U.S. Provisional Application No. 60/917,566, filed May 11, 2007.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] The present invention relates to laundering systems using ozone, and more particularly to tunnel washing using multiple-stage ozonated water and to laundering systems for applying gaseous ozone to fabrics.

[0004] 2. Background and Related Art
[0005] Ozone is a naturally-occurring gaseous component of fresh air and is one of the most powerful known disinfectants and oxidizers. Ozone is created naturally by lightning strikes and may be created artificially by passing electricity through oxygen molecules that consist of two oxygen atoms. The lightning or electricity splits oxygen molecules into two free oxygen atoms that combine with other nearby oxygen molecules to form ozone. The third atom of oxygen makes ozone very unstable and makes it a powerful cleaning and oxidizing agent.

[0006] While ozone is a gas at room temperature, some ozone can be dissolved in cold water to allow it to serve as a safe and effective cleaning agent. Because ozone is such a strong oxidant, it oxidizes approximately 3,000 times more quickly than chlorine, a commonly-used oxidizing agent used in laundering. However, there have been some difficulties in using ozone as a cleaning agent. First, there have been difficulties in delivering the ozone to the laundry system in a way that it will be most effective. Second, there have been difficulties in obtaining and maintaining ozone concentrations at an ideal level throughout a wash system such as a commercial washer, including a commercial tunnel washer. Third, there have been difficulties in preventing unwanted side effects of ozone use, such as increased equipment wear and the unwanted release of excess ozone.

BRIEF SUMMARY OF THE INVENTION

[0007] Implementation of the invention provides tunnel washer systems that generate ozone and dissolve the ozone in water at various stages of the tunnel washer(s). The ozonated water may be stored and re-circulated/recirculated to ensure that a proper level of dissolved ozone is present in any water delivered to the various zones of the tunnel washer. Ozone is dissolved in the water using a Venturi injector. Ozonated water may be delivered to multiple stages of the tunnel washer to ensure maximum cleaning efficiency and effectiveness, and the multiple stages may include a pre-wash zone, a wash zone, and a rinse zone. Water from at least the rinse zone may be recycled, filtered, and re-ozonated for use in one or more of the other zones. The ozonated water allows for improved faster washing at cooler water temperatures, saving water and energy costs and improving the wash results.

[0008] Further implementation of the invention provides ozone washing systems that provide for the controlled safe application of gaseous ozone to laundry in a washer. A negative air pressure or vacuum is applied to the washer through an ozone destruct unit to draw ozone through the washer from an ozone generator and to reduce inadvertent ozone leaks from the system. The ozone levels at various locations may be monitored and ozone generation and application may be controlled in response to the detected ozone concentrations, levels, and flow rates. In some embodiments, ozone may be destroyed/removed/reduced at the end of a treatment cycle by various processes in addition to the use of the ozone destruct unit, including the application of gaseous nitrogen as a flushing agent. The application of gaseous ozone using the inventive systems allow the ozone to treat materials and articles of clothing such as jeans to achieve a desired look and feel, such as an appearance of having been worn, by interacting with the fibers of the materials and articles of clothing.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0009] The objects and features of the present invention will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments of the invention and are, therefore, not to be considered limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0010] FIG. 1 shows a schematic view of a tunnel washer in accordance with embodiments of the present invention;

[0011] FIG. 2 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention;

[0012] FIG. 3 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention;

[0013] FIG. 4 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention;

[0014] FIG. 5 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention;

[0015] FIG. 6 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention; and

[0016] FIG. 7 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention;

[0017] FIG. 8 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention;

[0018] FIG. 9 shows a detailed schematic view of an embodiment of ozone generation, injection into water, and delivery equipment in accordance with embodiments of the present invention; and
FIG. 10 shows a schematic view of a washer system in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

A description of the embodiments of the present invention will now be given with reference to the Figures, which are expressly incorporated into this description by reference. It is expected that the present invention may take many other forms and shapes, hence the following disclosure is intended to be illustrative and not limiting, and the scope of the invention should be determined by reference to the appended claims.

Some embodiments of the invention include tunnel washer systems that generate ozone and dissolve the ozone in water at various stages of the tunnel washers. The ozonated water may be stored and re-circulated/re-ozonated to ensure that a proper level of dissolved ozone is present in any water delivered to the various zones of the tunnel washer. Ozone is dissolved in the water using a Venturi injector. Ozonated water may be delivered to multiple stages of the tunnel washer to ensure maximum cleaning efficiency and effectiveness, and the multiple stages may include a pre-wash zone, one or more wash zones, and a rinse zone. Water from at least the rinse zone may be recycled, filtered, and re-ozonated for use in one or more of the other zones. The ozonated water allows for improved, faster washing at cooler water temperatures, saving water and energy costs and improving the wash results.

FIG. 1 illustrates a schematic of a tunnel washer 110 in accordance with embodiments of the present invention. The tunnel washer 110 includes multiple zones, sections, pockets, chambers, or compartments ("zones") through which the laundry progresses during various wash and rinse cycles. By way of example, the tunnel washer 110 may have twelve zones (but may have more or fewer zones), with laundry generally flowing in one direction, and washer water generally flowing in an opposite direction (known as a counter-flow washer). In the illustrated embodiment, laundry is loaded into the tunnel washer 110 at a load zone 112, the laundry continuously progresses through various zones where washing and rinsing may occur until the laundry exits the tunnel washer 110 at an exit zone 114, which may include a water extractor or press to remove water from the laundry, and the laundry is removed for drying. As the laundry continuously progresses through the various zones of the tunnel washer 110, additional laundry may be essentially continuously added at the load zone 112 and removed from the exit zone 114, allowing the tunnel washer 110 to process large amounts of laundry in a relatively short time. The tunnel washer 110 may also process laundry continuously without any interruption in some instances.

Previously, such washers required the use of hot water to adequately clean the laundry. However, tunnel washers in accordance with embodiments of the invention, such as tunnel washer 110, do not require hot water to clean, and in fact, the use of hot water is detrimental to the use of ozone for cleaning. Specifically, it has been found that ozone is most water-soluble in cold water, and remains dissolved (and active) in the cold water for a longer period of time. If the water is too hot, then ozone does not dissolve in the water and/or is too quickly re-released from the water. For example, ozone solubility in water decreases to near zero between about 40 and 45 degrees Celsius (about 105-115 degrees Fahrenheit). Therefore, it is advantageous to ensure that the water remains cold during use in an ozone tunnel washer so that the ozone remains in the water where it can effectively interact with soiled laundry. Ozone also functions best at lower pH levels than conventional laundry systems, such as pH levels below 10.

Cold-water laundering with ozone is advantageous in that it greatly reduces energy costs associated with heating the water. Additionally, because ozone is such a reactive oxidant, the wash cycle time and/or steps may be reduced. Fewer wash and rinse cycles/steps equate to less water usage, decreasing the water and sewage needs of the laundry system, further improving the cost of laundering using the embodiments of the ozone tunnel washer. As hot water, high alkalinity (pH), large doses of chlorine bleach, and acid (sour) combine to break down the fibers in linens, towels, and other laundry items, ozone tunnel washers also lead to improved fabric life. This is accomplished due to lower pH levels, less chlorine bleach, cooler temperatures, and reducing the need for sour. The shortened wash and dry cycle times due to fewer wash and rinse cycles/steps also lead to improved efficiency and labor costs, improving worker productivity.

In embodiments of the invention, ozone may be produced and/or stored as needed, and is then introduced into the wash water before the wash water is introduced to the washer. Ozone may be produced by first concentrating and storing dry oxygen with an oxygen concentrator 116. The oxygen concentrator(s) 116 provide high-quality oxygen to an associated ozone generator 118. The oxygen concentrator(s) 116 include a compressor and a filter/drier that take in ambient air and remove moisture and nitrogen components from the ambient air to leave mostly oxygen. Once the oxygen has been separated from the environment, it is then available for conversion to ozone. Alternatively, oxygen may be provided by any other means, such as by oxygen supplied in a removable oxygen tank.

On-demand ozone generation is comparatively cheap and reliable when compared with the costs of and difficulties associated with heating water and/or ozone storage (gaseous ozone has a half-life of about three days at room temperature and ozone dissolved in water has a half-life of only about 20 minutes at room temperature). Therefore, in embodiments of the invention, ozone may be generated by the ozone generator(s) 118 continuously and/or on demand while the tunnel washer 110 is on. In some embodiments, the ozone generator(s) 118 may cycle on and off as needed to maintain an adequate amount of ozone for use with the tunnel washer 110 and, in some embodiments, some ozone may be stored until needed and may supplement the ozone generated on demand.

The ozone generator(s) 118 receives oxygen from the oxygen concentrator(s) 116 and may use the oxygen to create ozone by a process commonly known as corona discharge, although any method of generating sufficient quantities of ozone may be used. The oxygen may be received into a ceramic titanium discharge generator. Alternatively, the oxygen may be received into a corona discharge cell that has an electrified quartz tube. The electricity passing through the ceramic titanium discharge generator or the quartz tube in a corona discharge cell converts the oxygen gas into ozone, as described above. Any other method of ozone generation may also be used, including a ceramic tube dielectric ozone generator. The ozone so created may be stored as a gas for a period of time until needed, or it may be delivered immediately upon generation to the cold water to be used in the tunnel.
washer 110. Any excess ozone gas, as well as any ozone gas that may leak from the system, may be routed to an ozone destruct unit 120 that may catalytically convert the excess ozone back to oxygen gas. One catalyst that may be used in the ozone destruct unit 120 is manganese dioxide.

To minimize ozone release to the surrounding environment, the ozone destruct unit(s) 120 may remove any excess un-dissolved ozone from the ozone injection systems before ozonated water is delivered to the tunnel washer 110, as is illustrated in and discussed in more detail with reference to FIGS. 2-9. In this way, very little ozone off-gases from the washer water (very little ozone leaves solution once it is thoroughly dissolved), thereby minimizing ambient ozone levels in the air surrounding the tunnel washer 110. In some embodiments, ozone destruct unit(s) 120 may also be placed inside and/or around the tunnel washer 110 to remove any ozone out-gassed from the wash water or escaping from the tunnel washer 110. In some embodiments, although it has been found to be typically not necessary, one or more of the ozone destruct unit(s) 120 may be associated with a negative pressure means such as a blower, ventilation fan, etc. to ensure that ambient ozone levels remain below acceptable levels.

In washing operations, it is important that the ozone be dissolved in the water. Ozone in the air will not interact with the soiled laundry to assist in removing the soiling. Although several mechanisms have been used to dissolve ozone in water, some do not perform acceptably well or in a controlled fashion in a tunnel washer system. One potential ozone dissolving system is a bubble diffuser. In such a system, ozone is bubbled into a tank or column of water through a porous material at the bottom of the tank or column. As the ozone bubbles rise through the column of water, some ozone diffuses into the water. However, the amount of diffusion is difficult to control, this method releases more ozone off gas that must be removed and destroyed, and the column of water through which the ozone is diffusing must be between ten and twenty vertical feet to obtain reasonable aqueous ozone concentrations. Although it may be possible to provide such a column of water in a commercial laundry installation, it is typically inconvenient.

A better (at least faster and less space consuming) way to dissolve ozone in water is through the use of a Venturi injector. Venturi injectors deliver ozone to the Venturi injector in a pressurized water line. As the water flows past the Venturi injector, it creates a pressure drop that sucks the ozone gas into the flowing water where it can dissolve into solution. A Venturi injector has been used in so-called “sidearm” or “retraction approach” systems, but the sidearm approach is limited in its ability to deliver ozone to the laundry. In such systems, the washer itself acts as a storage tank for ozonated water. Therefore, the water is delivered to the washer before any dissolving of ozone in the water occurs. Then, the water is circulated from the tank through one or more Venturi injectors, and returned to the washer.

This approach has several limitations. First, the water is initially delivered to the washer without ozone in a first fill. Therefore, any later-delivered ozonated water must displace non-ozonated water to interact with dirt and perform its cleaning function. Second, the ozone concentration in the wash water begins low and is thereafter hard to control with certainty. Third, other chemicals are typically already added to the wash water, raising the pH level of the water beyond a level at which ozone will continue to exist in the water; as pH rises, the half life of ozone falls until it decreases to near zero at pH levels above 10. Fourth, in order for maximum ozone transfer into the water using a Venturi system, the ozone should be delivered with a proper flow rate and water pressure for ten to thirty seconds; however, in sidearm systems, the water is typically pulled out and reintroduced before all the ozone has dissolved, in less than about five seconds. Finally, the water is often already somewhat dirty, and it is more difficult to dissolve ozone in dirty water.

A better method of supplying ozone to the water is to pre-dissolve ozone in clean water in a desired concentration before the water is supplied to the washer. In this manner, the maximum effective ozone concentration may be delivered in a controlled fashion to the washer/wash wheel on the first fill before the laundry has become saturated with other (non-ozonated) water. This ensures the ozone quickly reaches the fabric and best performs its oxidizing function in cleaning the laundry. This method is illustrated in part in FIG. 1 and is illustrated in more detail in FIGS. 2-9. Using the illustrated methods, dissolved ozone concentrations of between 0.50 parts per million (ppm) to 1.50 ppm and more may be provided in the ozonated water. In some instances, as discussed in more detail below, even higher concentrations of dissolved ozone, such as 7 ppm may be desired and achieved.

The illustrated pressurized injection system and method use one or more separate storage tank(s) 122 for storing ozonated water. The system and method also use pumps 124 to drive the water through piping and across one or more Venturi injectors 126. The pumps 124 also deliver the ozonated water to the tunnel washer 110 and recirculate the ozonated water when water is not being delivered to the tunnel washer 110 so that ozone levels may be replenished as ozone naturally decomposes in the water. Pressure reducing valves (not shown in FIG. 1, but illustrated in more detail in FIGS. 2-10) may be used, if needed, to keep the water pressure at a constant desired pressure for proper dissolving of ozone in the water at the Venturi injector(s) 126. The system may also include various monitors and/or probes (shown as monitor 128 and illustrated in more detail in FIGS. 2-10), including an oxidation reduction potential (ORP) probe to monitor the ozone levels of the ozonated water and a pH meter to monitor the pH level of the ozonated water. The signals from the monitor(s) 128 may be used to signal increased ozonation or the addition of acid sour to reduce rising pH levels, if detected. The system may also include one or more of the ozone destruct units 120, as previously described.

Using such a system, water may be received at an input (either fresh water from a city supply, for example, or used water from a rinse cycle, as will be set forth below), and the water may be circulated through a closed circuit loop that includes the Venturi injector(s) 126, the monitor(s) 128, and the storage tank(s) 122 by the pump(s) 124. When fresh water is received from a city supply, its initial pressure may be reduced to approximately 50 psi by a pressure reducing valve (not shown). When used water is recycled, the circulation pump(s) may provide water pressures of between 5 and 50 psi.

During such circulation, a constant pressure across the Venturi injector(s) 126, such as between 10 and 20 psi, may be maintained as the water is ozonated to the desired level or full saturation. The circulation also ensures that the optimum ozonation is maintained in the full volume of water of the storage tank(s) 122 to be ready for use. When water is
called for by the tunnel washer 110, one or more valves may be opened to draw ozonated water from the storage tank(s) 122 and the water lines, and a fully charged load of ozonated water may be delivered to the laundry. Therefore, the storage tank(s) 122, and ozone injection systems may be sized so as to adequately meet any demand for fully-ozonated water. New water is then circulated, ozonated, and stored as the wash cycle continues, and is ready for use at the next time ozonated water is needed. After the ozonated water is delivered to the designated zone of the tunnel washer 110 and the laundry is saturated with the ozonated water, any chemical cleaners are then added and enhanced by the effect of the ozone in the water.

Thus, as may be appreciated, each and every fill of water may have a controlled, known, and effective amount of ozone in the water to maximize efficiency of the tunnel washer 110 and cleanliness of the eventual laundered load. To achieve maximum cleanliness of the laundered load and maximum efficiency, fresh ozonated (or re-ozonated) water may be injected at multiple stages of the laundering process within the tunnel washer 110, as illustrated in FIG. 1. The tunnel washer 110 of FIG. 1 includes three ozone injection points 130. One injection point 130 where freshly-ozonated water may be provided to the tunnel washer 110 is at a zone 132. At the zone 132, dirty wash water may be removed from the laundry, and fresh ozonated water (originally supplied directly from the city water supply) may be provided to remove any remaining soils and chemical cleaners. Although there may be some ozone remaining in the removed dirty wash water, it may generally be disposed of as any normal wash water would be: the ozone half life is short enough to prevent any problems, ozone in the waste water may actually assist in water treatment, and any remaining ozone is destroyed during waste water treatment. When the rinse water is removed from the zone 132, it is still fairly clean and need not be discarded. However, the ozone level in the rinse water may have decreased slightly or significantly, so it may be advantageous to re-ozonate the rinse water to a desired level if the ozone level has decreased as the water is recycled for further use.

Therefore, the water from the rinse water may be passed to a second ozone injection point 130 at a wash zone 134 (and/or to a third ozone injection point 130 at a pre-wash zone 136). At the wash zone 134, recycled water from the rinse zone 132 is re-ozonated (and may be stored in a tank 122 until it is needed) and may be combined with fresh ozonated water if necessary, such as where the amount of recycled rinse water is smaller than the amount needed for the wash zone 134. The ozonated water is then provided to the laundry in the wash zone and after the ozonated water is added and has saturated the laundry, chemical cleaners may be added. The ozone in the water enhances the performance of chemical cleaners, including chlorine, allowing the wash cycle to perform well at cold water temperatures, at shorter wash durations, and using fewer chemicals, resulting in energy and water savings and enhanced laundry life. Waste water from the wash zone 134 may be disposed of according to standard methods as set forth above.

To maximize efficiency of the tunnel washer 110 using ozonated water, the first fill of water that initially soaks the laundry may use ozonated water. Therefore, the third injection point 130 may be provided at the pre-wash zone 136 at the beginning of the tunnel washer 110 immediately following or concurrent with the load zone 112. The third injection point 130 at the pre-wash zone 136 may use fresh clean water from a city supply so as to maximize the dissolved ozone in the water supplied to the tunnel washer 110. Alternatively, the third injection point 130 at the pre-wash zone 136 may use a combination of fresh water from the city supply with recycled water from the rinse zone 132. Regardless, in this way, ozonated water immediately reaches all points of soiled laundry from the beginning, enhancing laundering success. It is anticipated that additional ozone injection points 130 may be added in embodiments of the invention while remaining within the scope of the invention.

As has been previously set forth, water in the tunnel washer 110 generally flows in a counter-flow direction to the direction of the flow of laundry in the tunnel washer 110. Also, as set forth above, the tunnel washer 110 may terminate in a water extractor or press (not specifically illustrated) that extracts and removes as much water as possible before the laundry is removed for drying. Because of the counter-flow nature of the water flow and the injection of clean ozonated water at the rinse zone 132, any water extracted at the water extractor or press is typically relatively clean, and in some embodiments, it is this extracted water that is recycled for re-ozonation and use at the pre-wash zone 136. In some embodiments, the rinse zone 132 may include several zones (pockets, etc.) with the water flowing in a counter-flow direction through the zones of the rinse zone 132. Thus, in some embodiments, the water that is re-cycled and re-ozonated prior to use in the wash zone 134 may be water removed from the first zone of the rinse zone 132 (having flowed through all later zones of the rinse zone 132). Although somewhat dirtier than the rinse water removed at the extractor or press, it has been found possible to substantially re-ozonate and re-use this water in the wash zone 134.

As is set forth above, ozone does not dissolve in warm to hot water and/or has a negligible half life in higher water temperatures. Additionally, ozone generation with hot air is more difficult and less effective. Therefore, embodiments of the invention embrace the use of monitors and cooling systems to ensure that the water and/or tunnel washer 110 remain cool enough for an effective amount of dissolved ozone to be delivered to the laundry. This may be important, for example, in hot climates, such as may be found in lower latitude desert-type locations such as in parts of Arizona. In such embodiments, the entire tunnel washer 110 may be enclosed and refrigerated if necessary to ensure that air and water temperatures remain sufficiently low. Alternatively, the entire in which the tunnel washer is located may be climate-controlled to ensure sufficiently low ambient air operating temperatures.

Alternatively, in other embodiments, the water supply temperature may be monitored and the water cooled or refrigerated, if necessary. In all such systems, the water temperature and/or the temperature of the tunnel washer 110 may be measured directly. Alternatively and/or additionally, a monitor such as monitor 128 discussed above may monitor the amount of ozone dissolved in the water being used and may sound and/or present an alarm or notification if the ozone level drops below an acceptable level, as would occur with water temperatures being too high.

FIGS. 2-10 illustrate more detailed embodiments of the ozone generation and delivery equipment discussed above, and the illustrated embodiments may be configured for different locations on tunnel washers such as tunnel washer 110 and for different sizes of tunnel washers, as may be
appreciated by one of skill in the art. The embodiments illustrated in FIGS. 2-10 are provided by way of illustration and not limitation, and are provided to assist one of skill in the art in practicing the invention.

[0044] FIG. 2 illustrates one embodiment of equipment that may be located at the rinse zone 132, or alternatively at the pre-wash zone 136 or even the wash zone 134, if no re-cycling or re-use of water is used at the pre-wash zone 136 or the wash zone 134. FIG. 3 illustrates one embodiment of equipment that may provide recycled and re-ozonated water to the wash zone 134. The embodiment of FIG. 3 may utilize a combination of fresh and recycled water. FIG. 4 illustrates one embodiment of equipment that may provide ozonated water to the pre-wash zone 136. The embodiment of FIG. 4 also may use a combination of fresh and recycled water.

[0045] FIG. 5 illustrates an alternate embodiment of equipment that may provide ozonated water to the wash zone 134. FIG. 6 illustrates an alternate embodiment of equipment that may provide ozonated water to the pre-wash zone 136. FIGS. 7-9 illustrate other embodiments that may provide or be modified to provide ozonated water to any of the zones in the tunnel washer 110.

[0046] In FIGS. 2-10, like reference numerals refer to like components. As one of skill in the art will appreciate and understand all the Figures by reference to them in view of the description, the following discussion will focus primarily on FIG. 2. In addition, a few comments regarding the additional features shown in FIGS. 3-9 are provided. In FIG. 2, oxygen concentrators 1 supply oxygen to ozone generators 2 as discussed above. Ozone is delivered from the ozone generator 2 to Venturi injectors 5 (see FIGS. 3-5) where it is dissolved in the water flowing in a recirculating loop as shown by the flow indicating arrows. As the water is recirculating, controllers 4 monitor the water for ozone concentration and pH and may signal any necessary changes as discussed above. One or more check valves 7 may assist in controlling the flow of water in the system, as will be appreciated from the Figures.

[0047] During recirculation, a substantial amount of ozonated water is stored in a storage tank 10. The storage tank 10 includes an air/ozone release valve 9 that allows any undissolved ozone or air to be released from the storage tank 10 through an ozone destruct module 11 as discussed above (no negative pressure means is needed for function of the ozone destruct module 11). Therefore, any undissolved ozone is removed from the ozonated water before the ozonated water is delivered to the various zones of the tunnel washer 110, substantially eliminating off-gassing from within the tunnel washer 110. As may be appreciated from reference to FIGS. 2-9, an ozone destruct module 11 may be provided for each ozone injection system, so if the tunnel washer 110 includes three ozone injection points 130, the tunnel washer may include three ozone destruct modules 11. Alternatively, the air/ozone release valves 9 of multiple ozone injection systems may be routed to a single ozone destruct module 11.

[0048] Pumps 3 keep the water circulating through the storage tank 10 to ensure that ozone concentrations remain at desired levels until water is demanded by the tunnel washer 110. When the tunnel washer 110 requests water, valves 16 open and deliver ozonated water from the storage tank 10 that is replaced by fresh water that is ozonated at the Venturi injectors 5 while water is not being demanded by the tunnel washer 110. Other components are illustrated to show the full assembly and functionality of the system, and will be readily understood by one of skill in the art.

[0049] Because the ozonated water supply equipment of FIG. 2 is designed to deliver a higher purity of water to the rinse zone than may be strictly necessary at other zones of the tunnel washer 110, the only water supplied to the system of FIG. 2 is fresh clean water from the local (e.g. city) water supply. Of course, in some embodiments, all ozone injection points 130 may be provided with ozonated water supply equipment similar to FIG. 2, and no re-ozonating of water after the ozonated water has been sent to the tunnel washer 110 occurs. In contrast, the ozonated water supply equipment of FIGS. 3 and 4 provides for recycling of water from the tunnel washer 110 through the equipment for re-ozonation and re-use in the tunnel washer 110.

[0050] The re-used water is first filtered to remove dirt and other particulate matter. The filtered re-use water still may have some ozone in it, and may be mixed with additional fresh water. As the recycled water in the system of FIG. 3 may be used with ozone dissolved in it, it may be possible to reduce the number or capacity of the oxygen concentrator(s) 1 and ozone generator(s) 2, as less ozone may be required for fully ozonating the water. In addition, the number of Venturi injectors 5 may similarly be reduced. In other instances (i.e. as illustrated in FIG. 4), the full ozone generation and injection capacity may be retained.

[0051] As may be appreciated, the re-used water may have appreciable quantities of detergents, sour, etc. in it. Therefore, as the water is circulated through the tank(s) 10 and the Venturi injector(s) 5, the injection of ozone may cause non-dissolving bubbles and foam in the water, which will naturally connect at or near the top of the tank 10. As the foam, in some instances, may cause difficulty for the ozone destruct module 11, an inline filter 14 may be provided to prevent the foam from passing to the ozone destruct module 11, and a tank top drain line may be provided that returns the foam to the tunnel washer 110, where it is not problematic. The inline filter 14 and tank top drain line may be provided in any instance where recycled water is being ozonated/re-ozonated. In other instances, the inline filter 14 and tank top drain line may be omitted when foaming does not occur. (See FIGS. 5 and 6.)

[0052] FIGS. 7-9 show additional ozonated water supply equipment embodiments of various sizes that may be used for wet ozone laundry applications including tunnel washers and other washers. The embodiments of FIGS. 7-9 do not depict utilizing recycled water, although it is anticipated that one of skill in the art will readily understand modifications that could be made to the illustrated embodiments as discussed above and illustrated at least in FIGS. 3 and 4 to utilize recycled wash water. The ozone laundry systems discussed above rely primarily on application of ozone to laundry while dissolved in water. Further embodiments of the invention include applications where ozone is applied to laundry as gaseous ozone, either in conjunction with ozone dissolved in water, or independently of any water washing. In instance where gaseous ozone application occurs in conjunction with water-dissolved ozone, the application of gaseous ozone may occur serially either before or after the application of water-dissolved ozone, or it may occur simultaneously.

[0053] Therefore, embodiments of ozone washing systems are disclosed below that provide for the controlled safe application of ozone, including gaseous ozone to laundry in a washer. A negative air pressure or vacuum is applied to the
washer through an ozone destruct unit to draw ozone through the washer from an ozone generator and to reduce inadvertent ozone leaks from the system. The ozone levels at various locations may be monitored and ozone generation and application may be controlled in response to the detected ozone concentrations, levels, and flow rates. The application of gaseous ozone using the inventive systems allow the ozone to treat materials and articles of clothing such as jeans to achieve a desired look and feel, such as an appearance of having been worn by interacting with the fibers of the materials and articles of clothing. Such gaseous ozone application systems are discussed with particular reference to FIG. 10. The system of FIG. 10 may be combined with wet ozone (i.e. dissolved in water) systems, such as those shown in FIGS. 2-9, as will also be discussed.

[0054] FIG. 10 shows a schematic view of an embodiment of a washer system according to the present invention. The system includes a washer 24 connected to an ozone generation and delivery system and further connected to an exhaust and vacuum system. The washer 24 may be a large commercial-type washer, and may be capable of typical washer functions and cycles. The washer 24 may be a custom-built unit, or it may be a standard washer modified for use in accordance with embodiments of the present invention. The washer 24 permits the application of gaseous ozone in precisely-controlled concentrations up to between 10,000 parts per million (ppm) to 20,000 ppm or more.

[0055] The controlled application of gaseous ozone is facilitated by the ozone generation and delivery system. The system includes an ozone generator 26 that takes a source of oxygen and converts the oxygen to ozone by known processes, as described above. Ozone may be produced by first concentrating and storing dry oxygen with an oxygen concentrator 28. The oxygen concentrator 28 provides high-quality oxygen to the associated ozone generator 26. The oxygen concentrator 28 may include a compressor and a filter/dryer that take in ambient air and remove moisture and nitrogen components from the ambient air to leave mostly oxygen. Once the oxygen has been separated from the ambient air, it is then available for conversion to ozone. Alternatively, oxygen may be provided by any other means, such as by oxygen supplied in a removable oxygen tank. Thus, any means of supplying oxygen to the ozone generator 26 is embraced by the embodiments of the invention.

[0056] In the illustrated embodiment, the ozone generator 26 receives oxygen from the oxygen concentrator 28 and uses the oxygen to create ozone by a process commonly known as corona discharge. The oxygen may be received into a corona discharge cell that has an electrified quartz tube. The electricity passing through the quartz tube in a corona converts the oxygen gas into ozone by splitting oxygen molecules into oxygen atoms that re-combine with other oxygen molecules to form unstable ozone molecules having three atoms of oxygen. Any other method of ozone generation may also be used, including a ceramic tube dielectric ozone generator as described above. The ozone so created may be stored as a gas for a period of time until needed, or it may be delivered immediately upon generation to be used in the washer 24. The ozone generator 24 may therefore be capable of producing sufficient ozone for all on-demand needs of the washer 24 (or washers 24 if plural washers 24 are provided), or multiple ozone generators 26 may be used as necessary to increase ozone production. Varying concentrations of ozone may be delivered to the washer 24 by controlling the amount of ozone generated by the ozone generator(s).

[0057] As ozone is a highly reactive gas, its environmental concentration should be minimized. Although this could be accomplished by making a completely sealed and leak-proof washer 24 and supply system, the cost of making a leak-proof washer system is high and is further complicated by any corrosion occurring from the ozone use. Instead, embodiments of the invention such as illustrated in FIG. 10 utilizes a vacuum or negative air pressure provided to the washer 24 through an exhaust system to pull air and ozone from the washer 24 to an ozone destruct unit 30. Any excess ozone gas, as well as any ozone gas that may leak from the system, may be also routed to an ozone destruct unit such as ozone destruct unit 30. The ozone destruct unit(s) 30 may catalytically convert the excess ozone back to oxygen gas as previously described. To ensure that no ozone leaks from the washer 24, a negative pressure means such as a blower, ventilation fan, vacuum pump etc. (referred to as “blower 32”) may be provided on the exhaust system to ensure that ambient ozone levels remain below acceptable levels. In some embodiments of the invention, one or more ambient monitors 34 may be provided to monitor ambient concentrations of ozone and/or oxygen and may provide a warning of unsafe conditions and/or may automatically discontinue ozone generation by the ozone generator 26.

[0058] In the system illustrated in FIG. 10, no ozone is recycled for re-use. It is relatively easy and economical to generate new ozone, and it is somewhat easier to control ozone concentration by generating new ozone as needed than it is to recycle ozonated air that may be contaminated with air entering the washer 24 due to the negative air pressure provided by the blower 32. Therefore, it is often easier not to recycle ozonated air but to simply destroy any excess ozone and generate new ozone as needed.

[0059] To minimize ambient ozone exposure and to maximally control the ozone applied to the washer 24, the washer system is provided with a negative air pressure means as described above. Additionally, the ozone is delivered to the washer 24 from the ozone generator(s) 26 and drawn from the washer 24 to the ozone destruct unit 30 through a piping system. The piping system includes one or more ozone feed line(s) 36, one or more ozone exhaust line(s) 38, and one or more ozone monitoring line(s) 40. The ozone feed line 36 connects the ozone generator 26 to the washer 24, and may be of a material resistant to degradation from contact with the ozone. The ozone exhaust line 38 connects the washer 24 to the ozone destruct unit 30 and the blower 32 and may also be resistant to damage from ozone. In some embodiments, the ozone feed line 36 and the ozone exhaust line 38 may be connected to the washer 24 in such a way that supplied ozone gas feeds into one part of the washer (such as a side or the bottom) and is extracted from an opposite part of the washer 24 (such as an opposite side or the top). In this way, ozone distribution throughout the washer 24 may be maximized. In other embodiments, ozone may be supplied to multiple locations in the washer 24 to achieve the same effect.

[0060] The ozone monitoring line 40 may be connected to various different locations on the ozone feed line 36, the ozone exhaust line 38, or the washer 24, and is connected to an ozone meter 42. This allows the ozone meter 42 to monitor the ozone concentration at any of the connected locations to ensure that the desired amount of ozone is being supplied to the washer 24 and to the clothing or other materials inside the
washer 24. Of course, where multiple monitoring lines 40 are used, multiple ozone meters 42 may also be used. To control the monitoring, as well as to control the supply of ozonated air and/or fresh air to the various systems discussed herein, the ozone feed line 36, the ozone exhaust line 38, and the ozone monitoring line 40 may be provided with various valves 44 and air inlets 46. By controlling the various valves, the ozone meter 42 may be selected to monitor ozone concentrations from just after the ozone generator 26, from just before the washer 24, or from just after the washer 24. Additionally, by controlling the valves and shutting off the ozone generator 26, fresh air may be taken in to the air inlets 46 to purge the ozone feed line 36, the ozone exhaust line 38, and the ozone monitoring line 40 of ozonated air. For the convenience of the reader, arrows have been added to FIG. 10 illustrating the direction of flow of air, whether ozonated or not, through the washer system.

[0061] A control unit (not shown) may also be connected to the flow meters (not shown) on the ozone feed line 36, and/or the ozone exhaust line 38 for additional information during control. Additionally, though not specifically illustrated in FIG. 10, the ozone generation systems and exhaust systems described above may be connected to multiple washers such as washer 24. In such embodiments, the valves 44 and the control unit provide additional control over the routing of ozone to the various washers so that ozone application may be occurring in one washer as another washer is loaded and/or unloaded, and so that ozone application (concentration and airflow rates) may be varied from one washer to the next.

[0062] Although not specifically illustrated in FIG. 10, an ozone washer system in accordance with embodiments of the invention may therefore include a control unit that may further include a computer. The control unit may control the washer 24, the ozone generator 26, the blower 32, and/or the various valves 44 in conjunction with the ambient monitor(s) 34 and the ozone meter 42. In this way, the control unit may precisely control the application of ozone to the washer 24 to a desired effective amount for an effective time. The control unit also allows for the use of precise formulations of ozone exposure for providing repeatable effects to materials in the washer 24.

[0063] For example, the ozone washer system of FIG. 10 may be used to provide a wearing effect on clothing such as jeans. To accomplish this, the washer 24 may be loaded with the clothing such as jeans to a desired loading. It has been found that for best effectiveness the washer should be minimally loaded, such as to approximately ten percent of capacity or twenty percent of capacity. The clothing such as jeans may be loaded dry, may be loaded in a wet or damp state, or may be loaded dry and wetted or dampened by the washer 24. Then, a desired ozone formulation may be applied using the ozone washer system as controlled by the control unit (and computer) while the washer runs at its normal speed (approximately 44 to 50 rotations per minute (rpm), for example). In some embodiments, the control unit may monitor and record data at multiple locations to allow for experimentation of the effect of the ozone at different concentrations and for different durations to determine a most desirable effect of the ozone. Additionally, programs may be designed to provide changing ozone concentrations during treatment to achieve desired effects. Thus, the embodiments of the invention may provide for customizable, repeatable application of ozone to various materials in the washer 24.

[0064] In some embodiments of the invention, the washer 24 may also be used as a conventional washer and/or the washer 24 may be used to wash clothing in ozonated water. In some embodiments, higher concentrations of dissolved ozone, such as 7 ppm may be used to further achieve certain effects, such as wear effects to the clothing. Such systems for providing ozonated water to the washer are illustrated in FIGS. 2-9 and described above. Using a system such as illustrated in FIGS. 2-9, the washer 24 may be used as a wet ozone washer and/or a dry ozone washer without requiring any loading or unloading of the washer 24 between uses. Therefore, a load of material may be consecutively treated with gaseous ozone and then with ozonated water (and any desired chemicals), or vice-versa to achieve additional desired effects for the material.

[0065] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed and desired to be secured by Letters Patent is:

1. A tunnel washer comprising:
   a. a plurality of zones for washing laundry in a continuous fashion;
   b. a first ozone injection point, a second ozone injection point, and a third ozone injection point, wherein each of the ozone injection points is located at a different zone of the plurality of zones and wherein each of the ozone injection points comprises:
   i. a water inlet to the zone of the tunnel washer, and
   ii. a circulating water loop connecting the water inlet and the water outlet, wherein the circulating water loop comprises a water storage tank and a Venturi injector for dissolving ozone in the water and an ozone generator receiving oxygen and delivering ozone to the Venturi injectors;

2. The tunnel washer of claim 1 wherein each ozone injection point further comprises an ozone destruct unit that removes excess un-dissolved ozone and converts it to oxygen.

3. The tunnel washer of claim 1 wherein the first ozone injection point is at a pre-wash zone, the second ozone injection point is at a wash zone, and the third ozone injection point is at a rinse zone.

4. The tunnel washer of claim 3 wherein the water inlet of the third ozone injection point receives water recycled from the end of the rinse zone.

5. The tunnel washer of claim 4 wherein the third ozone injection point comprises a storage tank and a tank top drain line for returning any foam to the tunnel washer.

6. The tunnel washer of claim 3 wherein the water inlet of the second ozone injection point receives water recycled from the beginning of the rinse zone that has passed through the rinse zone.

7. The tunnel washer of claim 1 further comprising monitors that monitor the pH and dissolved ozone concentration of the water in the circulating water loop.
8. The tunnel washer of claim 1 further comprising means for controlling the climate and for cooling the tunnel washer so that ozone may be generated and will dissolve and remain dissolved in the water.

9. The tunnel washer of claim 8 wherein the means for controlling the climate comprises a structure enclosing the tunnel washer and an air cooling unit.

10. The tunnel washer of claim 1 further comprising means for controlling the climate and for cooling the tunnel washer comprises a structure enclosing the tunnel washer and an air cooling unit.

11. The tunnel washer of claim 1 wherein the water delivered to the tunnel washer has ozone concentrations of between 0.50 parts per million (ppm) and 1.50 ppm.

12. A system for the application of gaseous ozone to fabric materials comprising:
   a) a washer;
   b) an ozone generator connected to the washer by an ozone feed line;
   c) an ozone destruct unit connected to the washer by an ozone exhaust line;
   d) a means for generating a negative air pressure connected to the ozone destruct unit so as to draw ozonated air from the ozone generator through the ozone feed line to the washer, and through the washer and the ozone exhaust line to the ozone destruct unit; and
   e) an oxygen source feeding oxygen to the ozone generator.

13. The system of claim 12 wherein the means for generating a negative air pressure comprises a blower.

14. The system of claim 12 wherein the means for generating a negative air pressure comprises a vacuum pump.

15. The system of claim 12 further comprising a plurality of washers connected to the ozone feed line and the ozone exhaust line, wherein a plurality of valves control the application of the negative air pressure and the ozonated air to the plurality of washers.

16. The system of claim 12 wherein the ozonated air has an ozone concentration between 10,000 and 20,000 parts per million.

17. The system of claim 12 wherein the ozonated air is applied to clothing in the washer to create a worn look for the clothing.

18. The system of claim 12 wherein the oxygen source is an oxygen concentrator.

19. The system of claim 12 further comprising a system for providing ozonated water to the washer comprising:
   a) an ozone generator;
   b) a circulating path of water including a water storage tank connected to the washer; and
   c) a Venturi injector on the circulating water path wherein the Venturi injector is connected to the ozone generator and receives ozone from the ozone generator and dissolves the ozone in the circulating water.

20. A method for the application of gaseous ozone to fabric materials comprising:
   delivering ozonated air to a washer system under negative air pressure wherein an air pressure inside the washer system is maintained at a lower pressure than an air pressure outside the washer system at all times that ozonated air is delivered to the washer system, the washer system comprising:
   a) an ozone generator connected to a washer by an ozone feed line;
   b) an ozone destruct unit connected to the washer by an ozone exhaust line;
   c) a means for generating a negative air pressure connected to the ozone destruct unit so as to draw ozonated air from the ozone generator through the ozone feed line to the washer, and through the washer and the ozone exhaust line to the ozone destruct unit; and
   d) an oxygen source feeding oxygen to the ozone generator.