Ozone—
Science & Technology—Minus the Myths
Part I

An overview of how ozone is created for use in commercial laundries and elsewhere

By Jack J. Reiff

With the crack of lightening and the roar of thunder, Mother Nature goes about her job of cleaning up our environment. Step outside after a thunderstorm and smell the sharp, clean crispness in the air. This is carona discharge of an enormous degree in a natural setting.

A walk in the sun, protected by the ozone layer in our atmosphere—using some of the sun's light waves (UV) to protect us from other more harmful sun rays—is another natural way mother nature works with ozone to benefit humankind along with other living species.

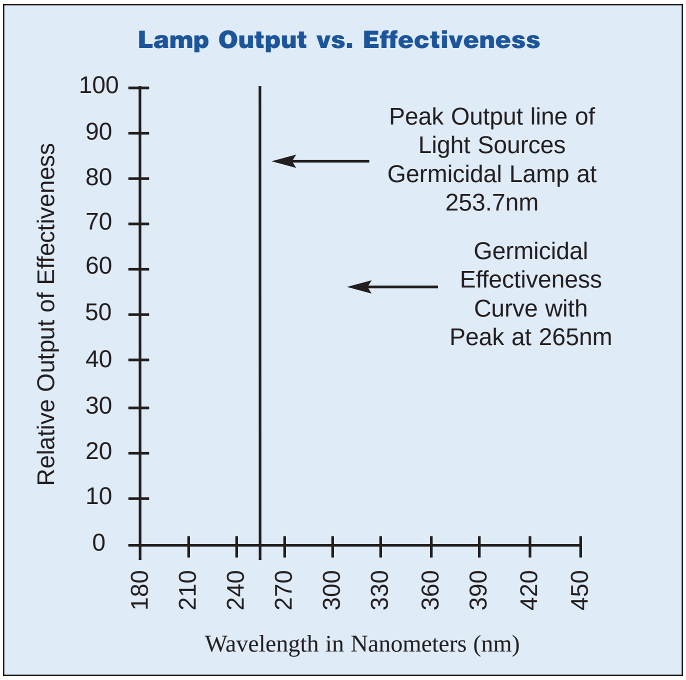
Ozone options, capabilities

There are several methods that can produce ozone. The natural way (as stated above) is carona discharge. There also is UV (ultraviolet) light, which happens naturally. This process (UV) is also known as the photochemical process of generating ozone.

Both methods can be reproduced by man in a mechanical/electrical manner. Another method is with electrolysis or electromechanical oxidation of water. Place electrodes in a tank of water and add an electric charge to excite the molecules. This releases ozone and oxygen at the anode terminal. No feed gas is required. A third process for generating ozone is with a cold plasma system. This process involves a glass tube filled with a mixture of inert gases and a small amount of mercury. An energy tube similar to a fluorescent light runs through the tube of inert gases and causes the gases to ionize at a low energy level and low temperatures.

There are various adaptations, combinations and arrangements of these generators that can enhance their applications in laundry and wastewater treatment, as well as keeping them within an efficient and economical operation. Some of these systems have some inherent design and operational restrictions that do not make them as desirable for use in laundry and wastewater treatment as the Carona discharge and UV methods.

All of these systems use a method of aggressive agitation to break up the oxygen molecules (O_2) so that these molecules temporarily attach themselves to other oxygen molecules (O_1), becoming (O_3)—ozone. One method of aggravation, carona discharge, is more aggressive than the UV light wave of ozone generation. These two systems, by design, almost establish the parameters for the present-day systems of ozone generation for our industry.



Discharge lamps placed in a glass tube with an inert gas generate UV radiation.

The history and facts of the benefits that the use of ozone offers humanity, especially in the healthcare, water treatment, waste treatment and the laundering of textiles have been discussed in previous articles. Documented data establishes the benefits of ozone in oxidation and sterilization, resulting in a quick return on investment (ROI) for ozone equipment.

Some pollutants can only be oxidized by ozone. For example, Cryptosporidium Parvum, a drinking water pollutant, is resistant to most chemical disinfectants, but is effectively destroyed by ozone. Some disinfectants act as a barrier to cysts but do not destroy them. Ozone eliminates them.

Flocculation is greatly enhanced; BOD, COD, FOG and other benefits abound with the use of ozone. It is important, then, to understand the manufacturing processes of ozone and making the

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application fit the product.

This two-part series on the science and technology of ozone will deal primarily with the manufacture of ozone through the use of the UV light (photochemical process) and the Carona discharge methodology.

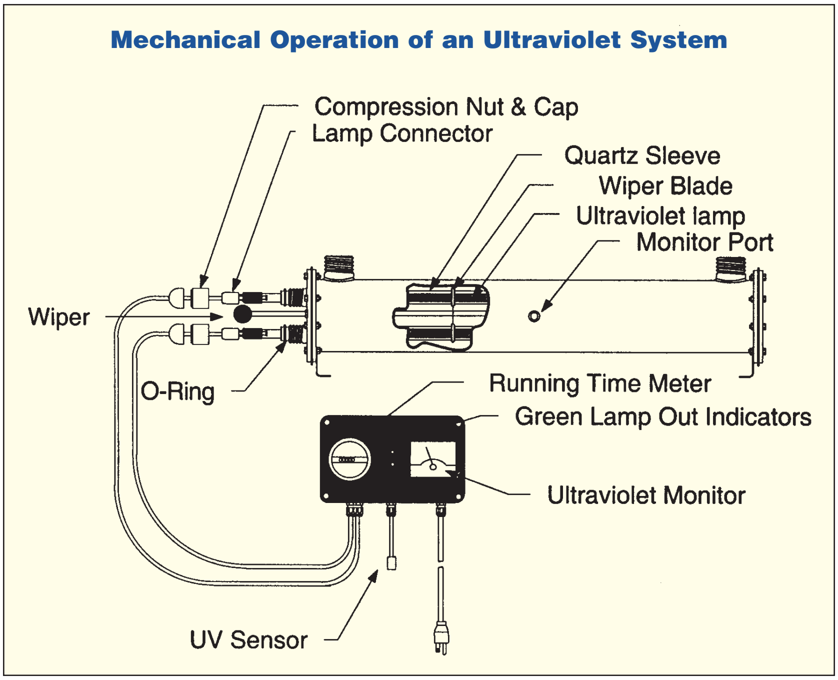
UV light (photochemical) process

Light comes in various colors based on the specific wavelength we can see. When atoms are exposed to high energy from any source, they tend to become excited and give off energy in the form of radiation. The nature of the radiation depends on the source, the excitation energy used and the media through which the radiation is traveling. The wavelength is measured as the distance between the peaks of a wave (angstroms) and the amplitude (height) of the wave. Light waves are measured with a nanometer and read in nm units.

The generation of UV radiation is through the use of discharge lamps placed in a glass tube with an inert gas. In this way, the UV process works much like cold plasma generation. The construction of the unit and its performance depends on several factors. The type of glass has one such effect on the wave. The glass can restrict the flow and intensity or distort the wave in some other way as it travels through the glass. The inert gases are another factor and are selected for the job at hand as well as the metallic substance, usually mercury, to achieve a specific wave of light.

Visible light is at a wave length of above 400 nm's. UV radiation, which for practical purposes, can be divided into four general intensities, is below 400 nm's. The categories of the UV light are UV-A, which is between 400 and 315 nm. UV-B is between 315 and 280 nm. UV-C runs between 280 and 200 nm, while the vacuum UV is below 200 nm. Vacuum UV is strongly absorbed by air; the UV-C is primarily used to destroy organisms. The level of nm's in the UV-C range that inactivates organisms is in the range of 253.7. It is interesting to note that the ozone-forming and the ozone-destroying wavelengths of UV light coexist at approximately 254 nanometers. It is for this reason that UV generators also are used as ozone destruct units. UV generators are rated by their capacity to treat water at specific flow rates. The UV dosage is the major consideration and is the product of the radiation intensity and the exposure time as is expressed in microwatts per square centimeter. It is this dosage that determines the unit's effectiveness and not the watt input or the radiated output of the UV lamps. The dwell time (exposure time) of the contaminants in the reactor determines the elimination of the organisms. General exposure alone is not enough. The dwell time can vary based on water flow in volume and/or velocity. The organisms to be eliminated must be in the conveying fluid and reside in the radiation zone long enough to absorb a lethal dose of UV light. For this reason most UV ozone systems must have a treatment chamber so that exposure to the UV is controlled. The UV lights are housed in a sleeve or jacket that is transparent to the UV radiation but acts as protection for the light source, as well as an insulator for the light to control the heat buildup.

The life span of the light source (the bulb) varies with age and the film buildup on the shell of the lamp. These two factors impede the proper generation of the UV light and interfere with the destruction of organisms. It is quite possible for a UV sterilizer/ozone generator to lose its intensity when the sleeves used for protection get cloudy from the mineral content or particulate matter in the water. For these reasons, the FDA and other agencies are specifying I-line UV intensity meters for output verification. There are various lamp




FDA and other agencies specify I-Line UV intensity meters for output verification. A UV sterilization/ozone generator can lose its intensity when sleeves used for protection get cloudy from mineral content or particulate material in the water.

sizes, intensities, internal pressure levels and outputs that can be matched to the design demand of a particular situation. Energy in is energy out, so check the design specifications to determine if they fit your needs.

Wastewater processing benefits

UV light works quite differently than Carona discharge generation of ozone. The method of operation with a UV light is to continuously expose the medium to be processed, whether it is air or water, through the high intensity light contained in the reactor tube. The light permeates through the medium and shines through any organisms that are in the air or water stream. The intense UV rays impact the sensitive RNA and/or DNA of bacteria, thus preventing the organism from reproducing. Bacteria, having a short life span, rely on rapid reproduction to flourish. UV rays essentially halt further growth or activity in these organisms. Unfortunately, since the UV light is only used within the small contact area, it does not provide residual disinfection in the water or air. One can see that the use of UV light is an effective tool, but one that does not prevent growth of bacteria unless it provides constant exposure. The ozone that is generated oxidizes the bacteria and particulate soil, thus destroying bacteria cells and preventing their reproduction. The ozone also oxidizes the soil or particulate matter, changing or destroying the chemistry of the soiling materials such as organic compounds. It is for these reasons and others that steps should be taken to ensure the purity of the UV generators, thereby ensuring the desired results.

Some real-world uses of UV technology as written about in *High Purity Water Preparation* by Theodore H. Meltzer and *Water Quality Products* by Adam Donnellan of Sunlight Systems are well established. The use of UV in destroying water-borne diseases is well established. Its use in the pharmaceutical, food, beverage, cosmetic, healthcare, manufacturing, high-tech manufacturing, wastewater treatment, cooling towers and laundry processing also is well documented.

Although UV is used to generate ozone, it is also used as on off-gas control and ozone destruct unit, controlling the ozone use to those areas of need.

Food and beverage manufacturers use the ozone to destroy the organisms that grow around these products. TOC (Total Organic Carbon) reduction is quite popular, along with dye stuff removal, chlorine neutralization, the processing of fresh food, drinking water, air conditioning, cooling towers and heat exchangers. Most of all, the wastewater generated by laundries through wash processing is altered in so many ways that the benefits to the industry are significant.

The second part of this series on the science and technology of ozone will discuss the Carona discharge process in ozone generation. **TR**

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Ozone—
Science & Technology—Minus the Myths Part II–Carona Discharge

An overview of how ozone is created and harnessed for use in commercial laundries

By Jack J. Reiff

What Mother Nature performs, science tries to duplicate and then works to improve upon. Ozone, created by a natural phenomenon—rain, thunder and lightning—provides so many benefits to mankind that science had to harness the energy and recreate the process.

This seemingly simple process that takes place naturally in the environment has taken the industrial society a long time to perfect. When it comes to ozone you could say, "Agitation leads to aggression and harnessed aggression leads to positive results." We recreate the process so that we can harness and apply ozone wherever possible.

Christian Friedrich Schonbein discovered ozone in 1840; in 1857 Werner Von Siemans developed a process for its general and industrial use. Experimentation and development continued in the search to improve on the generation of this fragile molecule that does so much, but readily decomposes back to oxygen.

Unhappy molecules

When stimulated (agitated) by either an electric charge or ultraviolet light (specific wavelength) the oxygen molecule (O_2) breaks up and temporarily joins other oxygen molecules forming O_3 (ozone), or other levels of ozone depending on the charge and feed source. These outside oxygen molecules are not happy in this new arrangement and seek to disengage themselves, creating an abundance of oxidizing power.

As stated in Part I of this series, there are several ways to produce ozone. The natural phenomenon of carona discharge, UV (ultraviolet light), photochemical or cold plasma have all been improved upon by science and technology so that the process now is relatively inexpensive.

Ozone, unlike most other chemicals, has no natural resource or method of storage. Ozone is generated on site and due to its rapid decomposition, it can't be stored for extended periods.

Carona discharge, one of the generation methods cited above, requires the energetic excitement of molecular oxygen to redistribute itself into atomic oxygen in the form of O_3. The silent arc discharge, also known as carona discharge or brush discharge, has become the preferred method of ozone generation when outputs above 1 gram/hour are required. (See exhibit 1)

Formation of Ozone

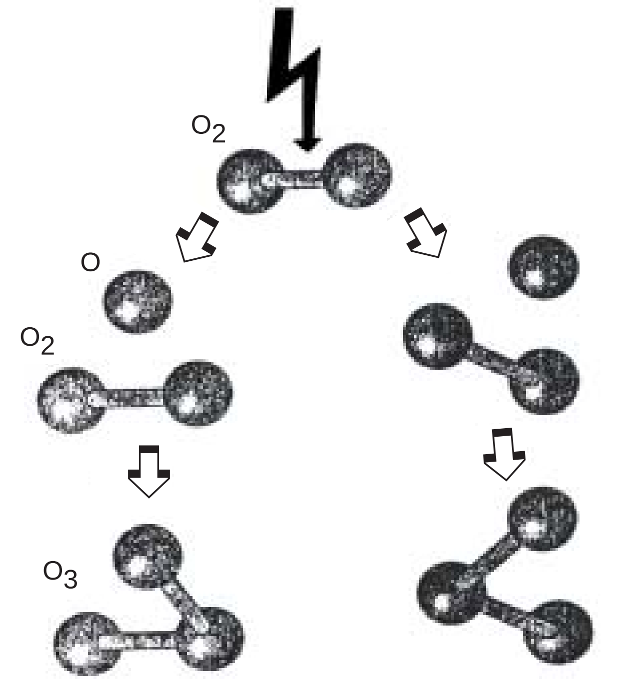

Exhibit 1

A carona discharge generator can take on many forms, shapes, sizes and ozone outputs. The required components of a basic silent arc carona discharge ozone generator are:

a) – two electrodes separated by a gap

b) – a dielectric material inserted into the gap

c) – a feed-gas flow containing oxygen inserted into the gap

d) – sufficient voltage potential between the two electrodes to cause a current flow through the gas.

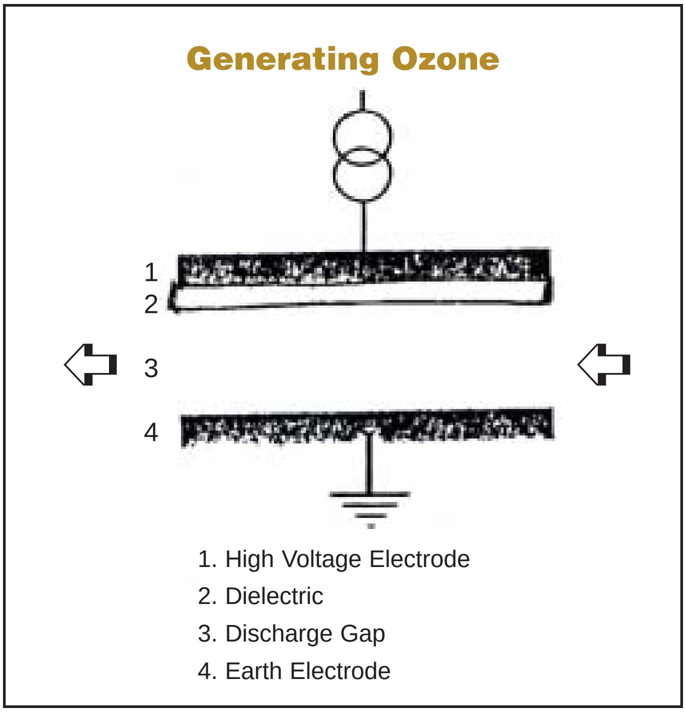

Exhibit 1A

The electrodes can be flat, tubular or in any other shape to provide a parallel position for energizing.

A typical ozone generator may take the form as shown in exhibit 2

This is a simplistic design that exhibits all of the attributes of a basic ozone generator.

In exhibit 3 (next page) there is an ozone cell that has been constructed from laboratory glass and formed to provide the proper design for ozone generation and to be able to direct the ozone concentration for specific uses. This is an early design that has been improved upon and simplified for today's ozone generators.

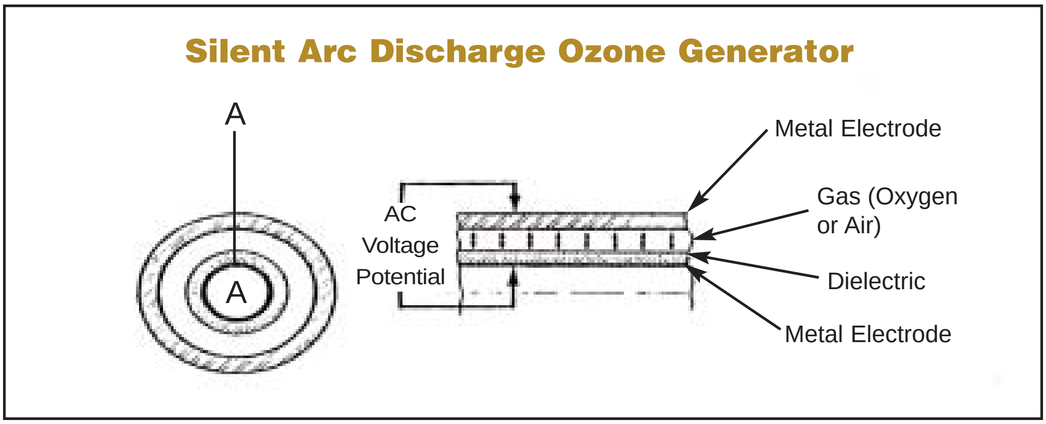

Exhibit 2

The reliability, performance and efficiency of the ozone generator depend on several factors. Since more than 80% of the applied electrical energy is converted to heat, the materials used in constructing the generator must be heat resistant. The heat generated must also be removed quickly and efficiently from the area or else the heat will accelerate the decomposition of the ozone generated.

Some ozone generators are water cooled. This method for small ozone generators can be costly, and in a laundry setting it can reduce the utility savings that are part of the rationale for using ozone.

Another method of cooling is through an airflow and/or refrigeration. With the proper use of airflow, heat is reduced and utility costs are not increased. Many manufacturers use heat sink devices in their design around the ozone components to direct heat away from the unit.

A process of balance

The generation of ozone is a process of balance and equilibrium. It is a process where ozone is being generated and yet destroyed concurrently. Feed gas decontamination is critical for good ozone generation. Heat, particulate matter, moisture, feed-gas flow (volume), pressure, vacuum, water conditions and other variables will affect the ozone quality and percentage of concentration.

This is one of many reasons that clean dry air or oxygen should be used in the generation of ozone. The U.S. Environmental Protection Agency (EPA) suggests that minimum moisture content below –60 dew point (frost point) should be maintained with the feed source.

Clean air, free of particulate matter, provides for maximum oxygen content in the volume of air being supplied as a feed gas. Dry air, again to maximize volume flow, also eliminates the potential for nitrous oxide development when the carona arc energizes the feed gas. Nitrogen oxide, converted to nitric acid, is detrimental to the operating equipment and catalytically destroys the ozone.

The selection of the dielectric material is critical in the performance, output and life of the generator. When considering the dielectric, it should be rated based on the continuous electron bombardment necessary to generate the desired ozone output. This same concern must be applied when selecting the electrodes.

To provide a sufficient voltage potential between the electrodes to generate the ozone, a transformer is incorporated into the system to step up the voltage and operate between 10,000-25,000 volts at low amperage. This voltage can vary based on the design characteristics for the ozone application. Some transformers are of the dry type where others can be encased in oil or be filled with silicone or other heat-control material to maintain low operating temperatures. The line voltage to the transformers can be 120 VAC, 230 VAC or 440 VAC in single phase or 3 phase at 50-60 hz.

Better than chlorine

Ozone is a gas that is virtually colorless and has an acidic odor. (That's ozone that you smell at the back end of your photocopier.) The gas has an electrochemical oxidation potential that is quite high and is superior to chlorine or other sanitizing products as shown in exhibit 4

The high oxidizing potential allows ozone to break down organ-

Cell Formed with Proper Design for Ozone Generation

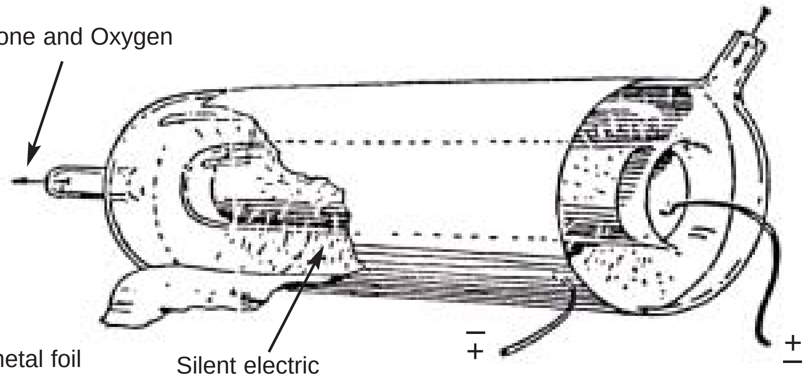

Exhibit 3

ic compounds that chlorine cannot. The pungent odor makes the presence of ozone immediately noticeable but not necessarily harmful. Most people can detect about 0.01 ppm in the air. This is well within the general comfort level of individuals. Symptoms that are experienced with concentrations at .01 to 1 ppm are headaches, irritation, burning of the eyes or respiratory discomfort.

When compared to the same exposure to chlorine, you will find that an exposure to 1,000 ppm of ozone for 30 seconds would be mildly irritating but the same exposure to chlorine is often fatal.

Ozone will attack and decompose organic and inorganic materials. Ozone attacks the molecules that bond many soils to the fabrics that we wash so it enhances the removal of these soils from the fabric. The oxidation of inorganic material helps in the process of treating soluble soil, making it insoluble so that it can be precipitated out of solution. This attribute is the basis for top-end wastewater treatment.

The potential applications, at present, seem unlimited. The untold advantages of ozone include environmental, economic and health benefits.

Harnessing and applying ozone

Now that we have produced the ozone, how can we harness and apply it for practical benefits? One of the simplest ways would be to use a venturi injector. This device, set into the stream of the water that is in use and to be infused with the ozone, creates a pressure differential from the inlet to the outlet side of the device. This pressure differential creates a low pressure (vacuum) in the outlet flow of the water. This low pressure or vacuum is the suction for the ozone feed line into the water flow. This type of application should be designed properly so that the loss of ozone in the vacuum does not inhibit the designed function of the ozone. The venturi system requires a water flow under pressure.

Another method would be with the use of a sparger, which allows the ozone to bubble into the water, under pressure, for dispersion in the water. This method provides for large and small bubbles of ozone to be applied and allows for off gassing unless destroyed.

Specifically designed diffusers, in my opinion, would be the most effective and efficient method of applying ozone in the wash liquor.

The ozone bubble size is controlled and will minimize off gassing. Bubble-size control is more effective when considerations are given as to the designated task of the ozone. Controlling bubble size also aids in the efficient dispersion of the ozone into the water. It is smart to remember that one size does not fit all applications.

Ozone is a chemical that when used properly can greatly enhance washroom technology and produce sound environmental and economic results.

Relative Power of Common Oxidants

Compound	Oxidation potential (Volts)	Relative Power of Chlorine
Flourine	3.06	2.25
Hydroxyl radical (OH)*	2.80	2.05
Atomic Oxygen (O)*	2.42	1.78
Ozone	2.07	1.52
Hydrogen Peroxide	1.77	1.30
Perhdroxyl Radical	1.70	1.25
Permanganate	1.67	1.23
Chlorine oxide	1.50	1.10
Hypochlorous acid	1.49	1.10
Chlorine	1.36	1.00
Bromine	1.09	0.08
Hydrogen peroxide	0.87	0.64
Iodine	0.54	0.40
Oxygen	0.40	0.29

*These ions are formed when ozone decomposes.

Exhibit 4

Part three of this series will deal with the application of ozone in the laundry industry. **TR**

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