A BASIC COMPARISON of OZONE TECHNOLOGIES
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Submitted by Ted Rich, Director of Sales & Marketing - ClearWater Tech, Inc.

The word is out, and the word is ozone. A wealth of information exists on this very powerful oxidizer - what it can do, what it can't, how to properly size a system, how it works, etc. Some information is general, some so complex that even the most versed water professional is left scratching his head.

This article endeavors to step back and provide a fundamental understanding of the variety of ozone technologies on the market today. Knowing how ozone is created and in what amounts and concentrations will assist the water professional in applying more complex information to determine which technology will provide the desired results most economically.

It has become common knowledge that ozone is generated in one of two generally accepted ways - by passing an oxygen-containing gas through either a high energy electrical field or through a source of ultraviolet radiation. The first method is known as corona discharge, the other ultraviolet.

Ultraviolet (UV) ozone generation
Two types of ultraviolet lamps have been marketed for use in water treatment: a mostly 254 nanometer (nm) lamp and one providing mostly 185 nm UV light. Light is measured on a scale called an electromagnetic spectrum and its increments are referred to as nanometers. Figure 1 represents an electromagnetic scale; note the location of higher-frequency ultraviolet light relative to visible light (the range of light perceptible by the human eye).

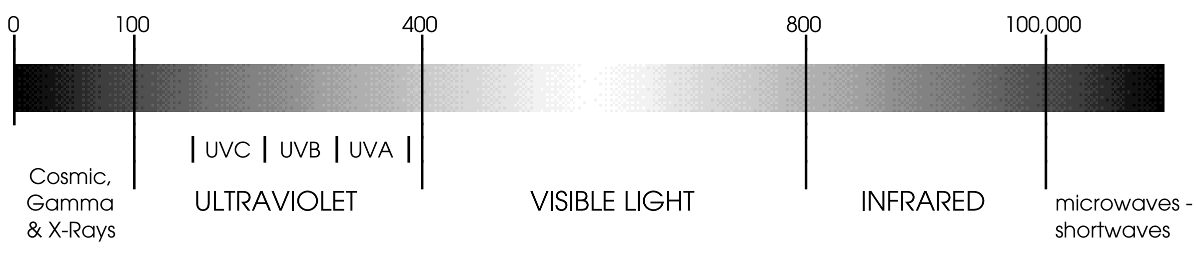

Figure 1 • Wavelengths in nm

The important distinction to make in this section is that ozone is not generated by 254 nm systems. In fact, ozone is actually destroyed by ultraviolet light at that frequency. 254 nm systems, referred to as ultraviolet sterilizers or germicidal sterilizers, inactivate organisms by affecting their ability to reproduce. Water is passed by the 254 nm lamp between a quartz glass sleeve and an outer chamber, usually made of stainless steel. It is the frequency of the light itself that impacts the organism, not ozone. Proper equipment sizing is essential for this method to be effective in treating water; the output of the lamp must match the flow rate of the water being treated. Intensity meters, hour meters and quartz sleeve cleaners are other features to look for in an ultraviolet sterilizer to maintain maximum ultraviolet radiation. In fact, local health officials may require that one or more of these features is provided on the equipment. Regular maintenance and lamp changes are mandatory to maintain the illumination required to inactivate contaminants.

Ultraviolet ozone generators, on the other hand, utilize a mostly 185 nm lamp to produce ozone. It is the ozone that impacts the water contaminants, not the ultraviolet light. Air (usually ambient) is passed over an ultraviolet lamp, which splits oxygen (O_2) molecules in the gas. The resulting oxygen atoms (O_1), seeking stability, attach to other oxygen molecules, forming ozone (O_3). The output gas is injected into the water, where the ozone in the gas inactivates contaminants by actually rupturing the organisms' cell wall. Look for an ultraviolet ozone generator with a reaction chamber made from a material that provides maximum reflectivity and is engineered to isolate wiring, electrical connections, etc. from the effects of ultraviolet light, heat and ozone.

Corona Discharge (CD) ozone generation

The technologies involved in corona discharge ozone generation are varied, but all operate fundamentally by passing dried, oxygen-containing gas through a high energy electrical field. The electrical current causes the "split" in the oxygen molecules as described in the section on ultraviolet ozone generation. Past this common feature the variations are many, but the generally accepted technologies can be divided into three types - low frequency (50 to 100 Hz), medium frequency (100 to 1,000 Hz), and high frequency (1,000 + Hz). Since 85% to 95% of the electrical energy supplied to a corona discharge ozone generator produces heat, some method for heat removal is required. Also, proper cooling significantly affects the energy efficiency of the ozone generator, so most corona discharge systems utilize one or more of the following cooling methods: Air, water with oil or freon, or water. Regardless of the CD technology you may select, be sure some type of cooling system is included.

At the heart of a corona discharge ozone system is the dielectric. The electrical charge is diffused over this dielectric surface, creating an electrical field, or "corona". Many different materials in a variety of configurations are used for the dielectric, including everything from silicone rubber (one design actually used radiator hose!) to scientific-grade glass.

Critical to CD ozone systems is proper air preparation. The gas feeding the ozone generator must be very dry (minimum -60 degrees F), because the presence of moisture affects ozone production and leads to the formation of nitric acid. Nitric acid is very corrosive to critical internal parts of a CD ozone generator, which can cause premature failure and will increase the frequency of required maintenance. If a corona discharge ozone system is selected, make sure air preparation equipment is part of the package. Figure 2 clearly shows the dramatic influence of feed gas dew point on ozone output.

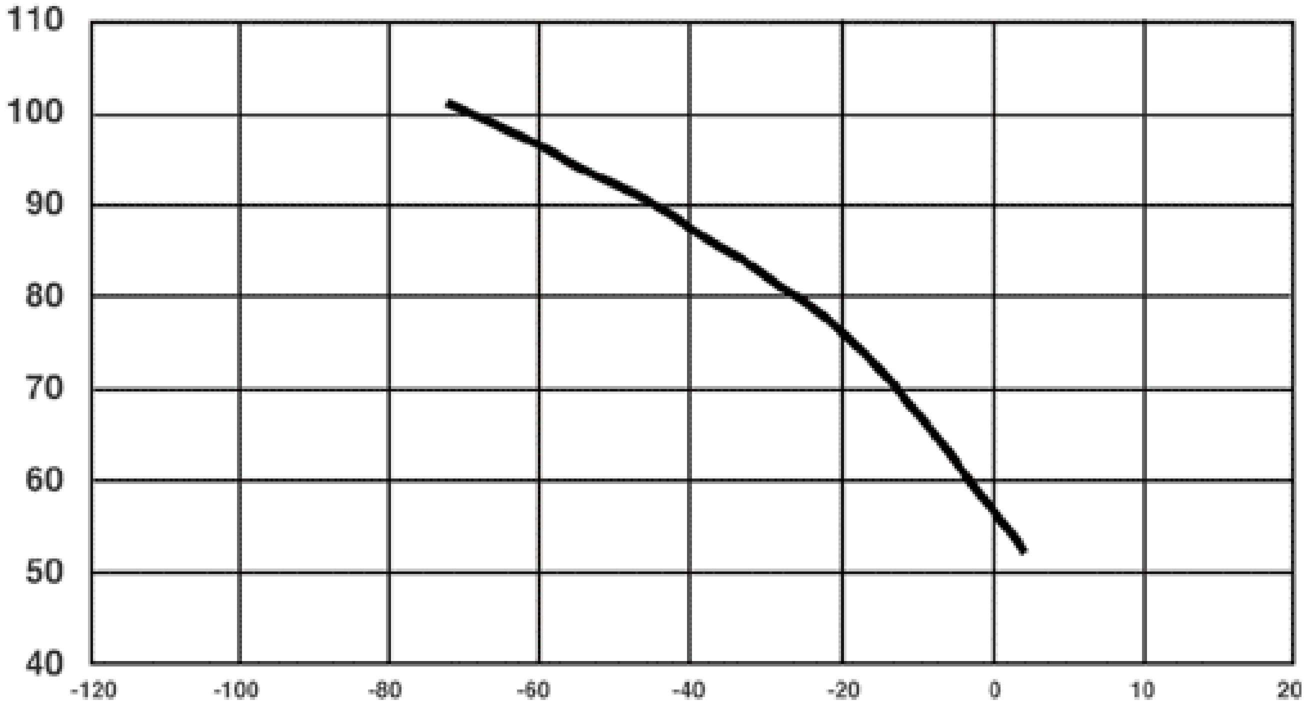

Figure 2. Effects of dewpoint on ozone production (Dimitriou, 1990).

Most large municipal ozone systems utilize the more traditional "iron lung" technology, incorporating low or medium frequency, water cooled generators. The feed gas is usually on-site generated oxygen. Examples of such installations include the Los Angeles Aqueduct Filtration Plant which has a 12,000 lbs./day ozone generating capability, and the Elm Fork water plant which can produce 16,665 lbs./day of ozone for the City of Dallas, Texas potable water supply. Virtually all metropolitan cities are now using ozone technology or have planned for its use in new or retrofit facilities.

Of the ozone technologies mentioned above, none has a clear advantage. However, to help narrow the field for a particular application, consider the amount of ozone required. You may find that low and medium frequency ozone systems will have prohibitively high initial costs for applications requiring less than ten lbs./day. However, they have a proven history of durability and reliability. High frequency ozone generators seem to have the best combination of cost efficiency and reliability for applications requiring less than ten lbs./day of ozone output.

Other more peripheral technologies have emerged on the ozone scene, including ultra-high frequency corona discharge and cold plasma designs (also known as cold cathode). The cold plasma method is actually an adaptation from the neon sign industry. The electrical power supply is often a standard neon lamp transformer or an ignition transformer from a oil burner. Cold plasma ozone generators utilize a glass lamp filled with a combination of inert gases that act as an electrode, while the glass acts as a dielectric. They normally operate at common frequency - 60 Hz compared to the 1,000 + Hz frequencies found in high frequency corona discharge generators. Since contact between the electrode and the dielectric is made less often in cold cathode systems, the amount of ozone generated by the same amount of electricity and over the same amount of time can be considerably less. Also, because low, medium and high frequency ozone generators have no lamps, they can be more durable and require less maintenance.

The Pros and Cons

Which technology is better? UV or CD? Low frequency, medium frequency or high frequency? Naturally, a simple, clearly defined answer would be nice, but it is not that simple. With that in mind, it may be best to summarize some key factors to consider when selecting the best technology for a particular application.

First, it is important to understand what conditions you are endeavoring to treat. It has been said many times before, but a complete water analysis is very helpful in determining ozone needs. Depending on what is being treated, the concentration of ozone in the output gas is every bit as important as the amount (usually shown in grams/hour) of ozone produced by the generator. Ultraviolet ozone generators generally produce concentrations of between 0.1% and 0.001% by weight, while corona discharge systems can produce between 1% and 6.0% by weight. Concentration significantly impacts the effectiveness of ozone because it must first be dissolved before it can react with water borne contaminants, and the higher the ozone concentration, the more soluble ozone is in water. Finally, if disinfection is the goal, higher ozone concentrations are required; consider the available corona discharge technologies instead of ultraviolet ozone generators.

While the most important points may be "how much ozone" and "in what concentration," there are cost considerations as well. If it has been determined that low outputs and low concentrations can do the job (for example, treating small amounts of iron or certain odor problems), ultraviolet ozone generators can be cost effective. Since ambient air is used as the feed gas, ultraviolet systems do not require air preparation equipment. However, ozone output fluctuates according to changes in humidity and because UV lamps gradually lose their intensity over time.

If greater ozone outputs and concentrations are required for an application, a corona discharge technology should be chosen. The use of a high, medium or low frequency system will depend on matching equipment costs with ozone output requirements. Cold cathode ozone generators utilize somewhat fragile lamps and employ relatively simple technology, but can carry lower price tags because manufacturing costs are comparatively low.

Summary

The ozone generation technologies available today are many. Taking on a wide variety of shapes and sizes, all are different in their outputs, electrical efficiencies and overall costs. Selecting the proper system for each application becomes a matter of evaluating ozone output and concentration requirements, then looking at quality (use of ozone-resistant materials, warranty, etc.), durability and experience in the type of application for which ozone is being considered.