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Using Ozone For Water Treatment

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Whether produced by nature or humans, ozone is one of the most powerful disinfectants available. Properly applied, it destroys most, if not all, bacteria, viruses and other pathogenic organisms.

Ozone is an unstable form of oxygen. In the upper atmosphere, it is contained in the much-publicized "ozone layer." In this layer, the sun's ultraviolet light forms ozone by splitting oxygen molecules into atoms. Some of these atoms combine with separate oxygen molecules to form ozone.

Natural and artificial processes manufacture ozone in the lower atmosphere. Lightning is the most familiar way ozone is naturally manufactured. Some artificial sources of ozone include electric motors, copiers, laser printers and fluorescent lights.

Ozone in Water Treatment

In 1857, Werner Siemens developed a method of producing ozone by silent electrical discharge. His invention paved the way for ozone's use in water treatment, including the first full-scale application of ozone in drinking water treatment in 1906.

Ozone was first used in cooling tower water treatment in the late 1970s when government and private concerns conducted research on its effective use.

Today, ozone is gaining rapid acceptance in hospitals, commercial office buildings and industrial plants for a wide range of applications including cooling tower water treatment, food and food processing, waste water cleanup, smoke removal, swimming pools and spas, drinking and bottled water, and pulp and paper bleaching. Ozone is used where reliable biological control is needed and residual chemical compounds are undesirable.

When ozone reacts with an organic, the byproduct is oxygen and an oxidized form of the organic. In addition, unused ozone naturally and quickly decays to oxygen. These factors make using ozone for biological control an attractive choice.

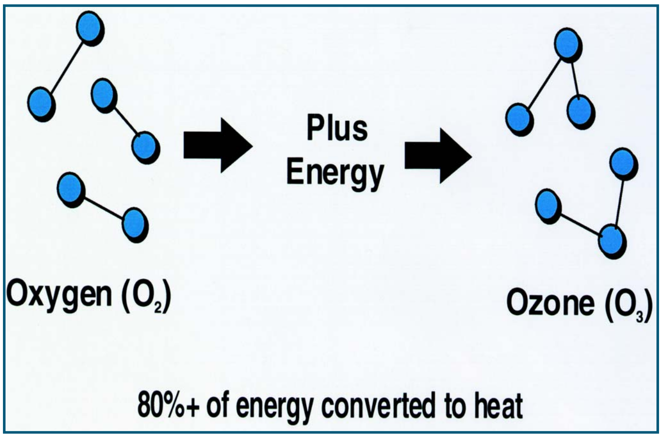

Figure 1: Ozone generation by corona discharge.

Ozone in a Cooling System

Ozone is an excellent biocide. It oxidizes not only bacteria, but also organic food sources for those bacteria. For example, in one study, ozone killed existing algae in the cooling tower basins and sidewalls. A mat of algae over 0.25 in. (6 mm) thick was allowed to grow in a cooling tower basin. When ozone was applied and the oxidation reduction potential (ORP) level maintained at 750 millivolts, the algae turned from bright green to dark green within one day, dark green to brown within four days and sloughed off within a week.

Maintaining an ORP above 500 millivolts generally is necessary to maintain an acceptable bacteria count. In the study, the ORP was lowered gradually from the standard 750 millivolts. Below 500 millivolts, bacteria and algae growth was essentially uncontrolled. In a cooling tower properly treated with ozone, total bacteria counts of 10^3 are achieved routinely. The clarity of the water rivals that of the best-maintained swimming pools.

Scale control in a cooling system is important for efficient operation. Ozone's primary contribution to scale control is the fact that it is an excellent biocide. Scale adheres to a biological layer, often called slime. Cooling systems properly treated with ozone will have no slime layer for scale particles to adhere.

Maintaining water quality is also essential to maintaining a scale-free system. At higher cycles of concentration, calcium and carbonate will precipitate from solution to suspension as the most common form of scale, calcium carbonate. In a clean system, these scale particles will settle in the low velocity area of the cooling system—often the cold water basin of the cooling tower. Removal of suspended minerals by blowdown, filtration or physical cleaning may be necessary.

In general, maintaining a positive Langelier Saturation Index (LSI) of 1.5 to

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2.5 in the circulating water allows reasonable water savings while keeping scale deposition to a minimum. Water velocities, temperatures of the heat transfer surfaces and system configuration also affect the tendency of a system to form and accumulate scale.

Generally, ozone is not considered a corrosion inhibitor. However, experience based on corrosion studies performed on over 75 sites across the country—some with over eight years of coupon analysis—indicate corrosion rates in a cooling water system can remain well within industry acceptable limits. Most of these sites operate with mild steel corrosion rates, measured by coupon analysis, of less than 2.5 mils per year (mpy). Copper corrosion rates average less than 0.3 mpy, with some so low they cannot be measured on a 90-day coupon. Extremely soft waters that cannot be cycled up, or waters with high levels of chlorides will require the use of corrosion inhibitors to maintain acceptable corrosion rates by industry standards.

For example, on one tower installation the copper corrosion rates approached 1 mpy. This system had soft water, a low heat load, a large water volume and major leaks in the system. This combination kept the water from cycling to normal hardness levels.

A commercially-available copper corrosion inhibitor was introduced into the system in a single dose and the corrosion rates remained acceptable throughout the year. After the leaks were corrected, cycles of concentration elevated and corrosion rates decreased to acceptable levels.

A clean system will have lower corrosion rates due to less micro-biologically-induced corrosion. Maintaining a hard or alkaline water quality where calcium carbonate has a tendency to precipitate results in a less corrosive water than a soft or acidic water. Removing the precipitated solids from the water reduces the occurrence of under-deposit corrosion.

Ozone, although an excellent treatment option, does not work as a stand-alone treatment on all systems. High heat exchanger skin temperatures can cause scale to adhere in a manner that ozone cannot prevent.

Well water may be so hard that it cannot run through the system even one time without scaling. In the following example, a cooling tower cools electrical leads for a foundry. Although the makeup water source is city water, it is drawn from wells. The LSI of the makeup water is 2.75. This high LSI coupled with the high skin temperature of the electrical leads, caused an unacceptable scaling on these leads.

The amount of ozone required to treat a cooling water system is dependent on a number of factors: water flow rate to the tower, water volume, water temperature (higher temperatures shorten the life of ozone), bacteria count and organics in the incoming water, and organics in the air (cooling towers clean the air well).

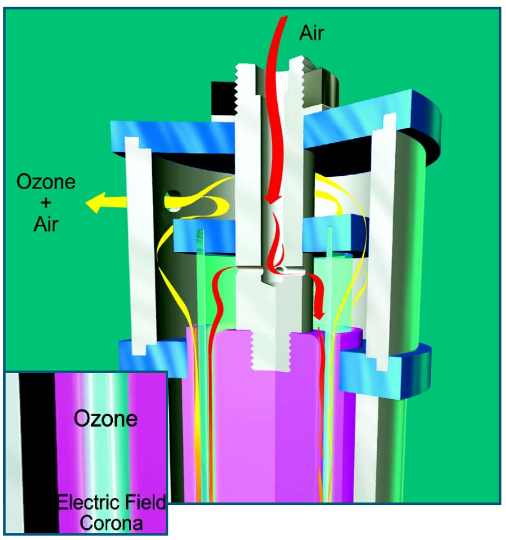

Figure 2: Air or oxygen is passed through the gap between two conductors, which results in some of the oxygen converting to ozone.

Waters that are high in organic content, such as river or "gray" water (primarily treated sewage), are sometimes used as makeup water. These waters require significantly larger amounts of ozone than the normal city water used in most HVAC and light industrial systems. This is because the city water treatment process has already removed the bacteria present in river or gray water, which reduces the ozone demand.

In this case, the scaling reduced the water flow, increasing temperature and scale deposition until the water passage was totally blocked. Partially softening the makeup water reduced the scaling tendency adequately on this system and actually resulted in overall cost savings.

Manufacturing Ozone

Ozone for use in cooling water treatment is made by corona discharge or ultraviolet light. Corona discharge involves generating an electric field between two conductors. The ultraviolet method uses ultraviolet light to break the bond between oxygen molecules. Some of these oxygen radicals then combine with other oxygen molecules to form ozone. *Figure 1* shows a simplified reaction. For most cooling water applications, corona discharge is the method of choice because ultraviolet light produces less than 0.5% ozone versus about 1.5% for corona discharge for the same energy input.

Production of ozone using corona discharge occurs when a high-energy electric field exists between two conductors (with gas containing oxygen between the conductors). Typically a 4,000 to 10,000 volt electrical potential is placed on two conductors spaced about 0.3 to 0.6 in. (10 to 15 mm) apart. Air or oxygen is then passed through this gap with the result that some of the oxygen is converted to ozone (*Figure 2*).

A typical generator produces about 1.5% ozone by weight for air. Using 90% or higher oxygen concentrations instead of air will generate up to 13% ozone by weight depending on gas flows and cooling efficiency. The energy required to produce a pound of ozone is about 11.5 kW using air and is about 4.5 kW using oxygen. Most of the energy input (80% to 90%) is converted to heat and must be removed by some form of cooling.

How an Ozone Generator Works

The main components of an ozone system are the gas feed preparation system, the generator and the contacting and delivery system (see *Figure 3*).

Clean, dry feed gas (air or oxygen) is important to ozone generator operation. Water vapor in the air combines with nitrogen and forms nitric acid. In air with a dew point above –40°F (–40°C), the nitric acid formed will not be enough to depress the pH of the circulating water, but it usually will corrode the electrodes.

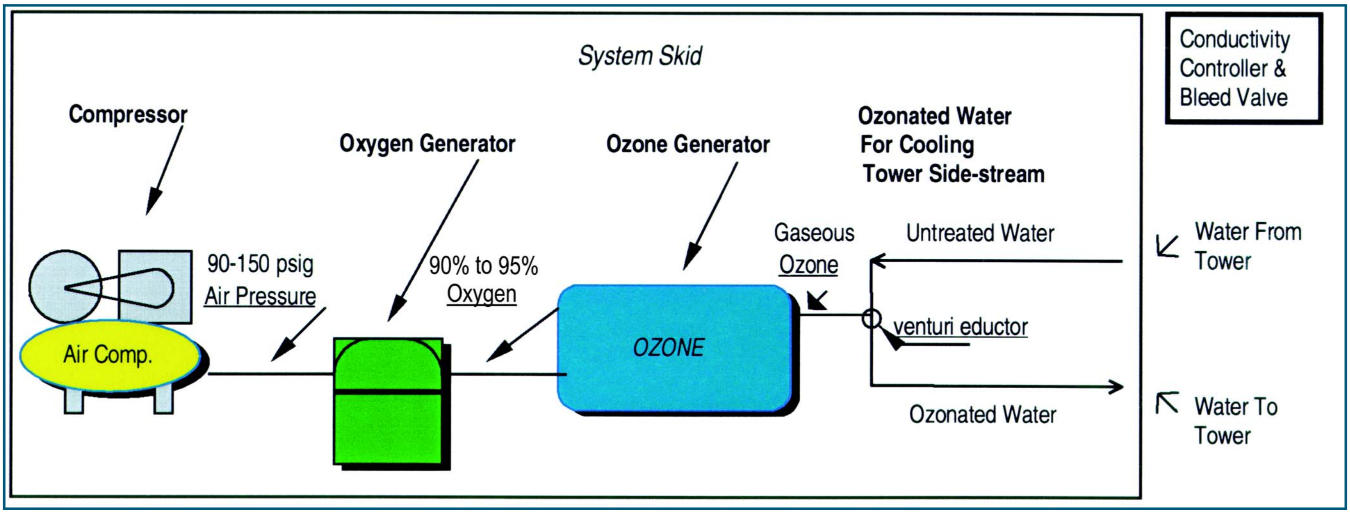

Figure 3: Major components of ozone water treatment system.

Using an air compressor with a production capacity of at least twice that of the air consumption of the generator prolongs the life of the air compressor. A high quality air compressor minimizes maintenance and downtime. Using oil-free compressors where practical helps to minimize the chance of getting oil in the ozone generator. An auto-drain on the compressor tank automatically removes water condensed in compression.

Because more than 80% of the electricity used in the production of ozone is converted to heat, adequate cooling is important. Common methods of cooling the electrodes include air cooling, refrigerating and water cooling. With refrigeration, a small refrigeration coil removes heat from the electrodes. Cooling water generally comes from one of three sources: the cooling tower cold water basin, the makeup water source or the chilled water loop. All of these methods are effective at removing heat from the electrode. The generator manufacturer incorporates cooling into the generator and can recommend alternative methods if necessary.

Each manufacturer controls ozone production differently. Three common ways of control are using a potentiometer, ORP controller or no control. With a potentiometer the user must adjust the output based on some method of determining ozone requirements. With an ORP (oxidation-reduction potential) controller, a probe (similar to a pH probe) measures the level of oxidants in the water. Although this is not a direct measure of ozone, ozone is the only oxidant normally added to the system. The ORP controller uses high and low set points to control the production of ozone. The downside of ORP is that the probe requires maintenance to be accurate.

Generally, it is not recommended to operate an ozone generator without monitoring or some form of automatic and manual control. Usually, the ozone demand varies significantly throughout the cooling season. The demand may swing from 10% of the generator capacity to 100% with the changing conditions of outside temperature, heat load and organic content of the air and water. Excess ozone production wastes energy, can accelerate corrosion and result in excessive off gassing in the area of the distribution piping.

Methods to determine the ozone demand include visually inspecting the tower for algae and/or making actual bio-counts. If there is algae growing in the water, there is probably slime throughout the system, which can be removed by increasing the ozone output. Making bio-counts, usually by dip slides, is a 48-hour process, which delays monitoring by two days.

Advantages of Ozone Water Treatment

- Reduced risk of Legionnaires Disease: ozone is an extremely efficient biocide.
- Reduced operating costs: chemical and water savings coupled with improved operating efficiencies reduce system operating costs.
- No chemical handling, storage or discharge problems. Ozone is generated on-site as needed.
- Automatic control insures adequate treatment.

Disadvantages of Ozone Water Treatment

- Initial capital expense—However, as the technology of ozone generation and mass transfer improve, systems that five years ago had paybacks of five to six years now have paybacks of two to three years.
- Limitations of temperature and water quality:
  1. Hot water temperatures above 120°F (48°C) and cold water temperatures above 100°F (38°C) should be avoided.
  2. Plan to partially soften water using pH control or other means to reduce scaling tendencies of makeup waters with a LSI of 2.0 or higher.

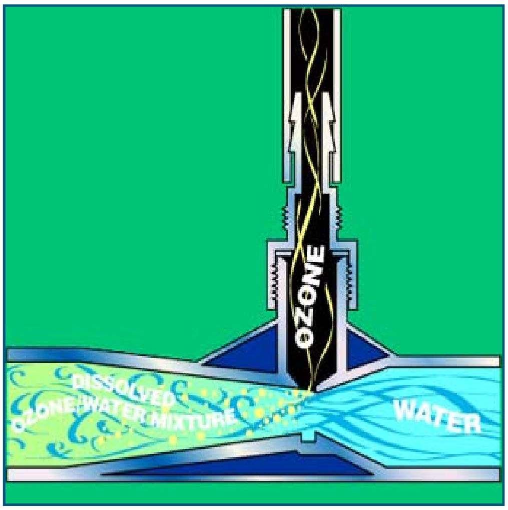

Figure 4: Typical ozone/water mixing using a venturi eductor.

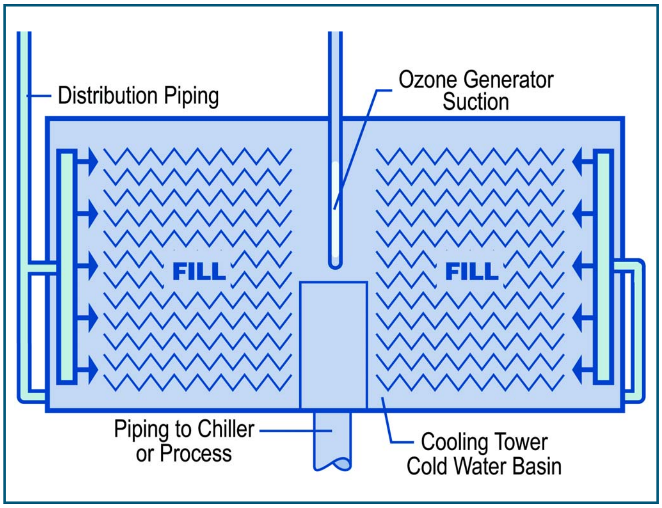

Figure 5: Ozone distribution/piping layout for a typical cross-flow cooling tower cold water basin.

The use of ORP, while an indirect method of measuring ozone, is the most common method of determining the amount of ozone needed and produced. This method minimizes the time required from plant personnel, provides a constant level of oxidant with changing conditions and uses the least amount of energy to maintain the proper ORP level. ORP sensors are commonly placed in the side stream. It is important that the water sample passing over the probe is representative of the amount of ozone going to the heat exchanger equipment.

A typical contacting system consists of a side-stream pump and a venturi eductor (*Figures 4* and *5*). The water in which the ozone is dissolved is usually a 2% to 7% side-stream of the circulating rate of the tower. The side-stream pump suction usually is placed somewhere close to the supply to the heat load. The water is pumped through the eductor where ozone and water are mixed. Over 90% of the ozone can be transferred to the water with this type of mixer. From the eductor the water containing ozone and the ozone-depleted air are pumped to the cooling tower cold water basin. Distribution normally is done by using a PVC pipe with distribution holes at the louver face of the cooling tower.

Telemetry is common and can be used to remotely monitor the system status. Several types are available and multiple inputs allow monitoring of conductivity and pH as well as ORP and fault lights. The telemetry system is a data logger that records data over several days. This data can be examined to establish the "normal" rhythm of generator operation. Many potential service problems such as fouled probes or faulty blowdown valves can be diagnosed by evaluating the data. This minimizes downtime and emergency service requirements.

Conductivity and pH controllers are other peripheral devices installed on systems. These devices maintain water quality automatically. Maintaining water quality is important to prevent scale buildup on heat exchange surfaces. The conductivity controller eliminates the need to manually measure the conductivity and blowdown to acceptable limits. Conductivity controllers are highly recommended for any cooling tower system.

In some installations the ozone needs to be injected into an indoor storage tank. Because not all of the ozone dissolves in the water, off-gas control is important to prevent ozone concentrations from exceeding the OSHA limits of 0.1 for an eight-hour time weighted average, or a 0.3 short-term exposure limit.

The process of preventing ozone from being released into closed spaces is straightforward. Undissolved ozone is removed from indoor tanks by venting covered tanks, adding a cover and vent to other tanks, or adding a de-gas tank and vent in other situations. If desired or needed, a vent fan and ozone destruct device can also be added.

Conclusion

Using ozone in cooling tower systems is an excellent method of water treatment. In a large number of applications, ozone can effectively replace chemicals and help to maintain the high quality water needed in cooling towers.

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