Ozone

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Fundamentals of Ozone

By Bob Smith-McCollum

Mastering the fundamentals of ozone is critical to successful design and implementation of efficient and effective ozone systems. This mastery is achieved through a clear understanding of the key elements of ozone, as well as their interactions and impacts on the performance of the overall system.

For the purposes of this discussion, we will focus on ozone systems in which the ozone gas is dissolved into water and applied to the target application.

A Piece of Cake

It could be said that constructing an ozone system is much like baking a cake. Well-designed ozone systems are comprised of fundamental components that must be properly interconnected to form an integrated ozone system.

Four basic elements are required to form fully functional ozone systems:

- Oxygen/feed gas preparation;
- Ozone generation;
- Mass transfer; and
- Monitoring and control.

All four components must be present to create a smooth-running ozone system. None is more important or less critical than the other. Going back to the cake-baking analogy, a cake is comprised of four basic ingredients: flour, sugar, shortening and eggs. All are essential, each is required, and without all four there is no cake. All of the basic elements of ozone systems must be present and properly combined to construct a successful system.

The importance of learning the elements of ozone, their interactions and impacts in a one-step-at-a-time approach

Oxygen/Feed Gas Preparation

Ozone systems convert diatomic oxygen (O_2) from the atmosphere to ozone (O_3). Nearly 21% of the air that we breathe is comprised of diatomic oxygen. Depending on the requirements of the application and the capabilities of the ozone system, the feed gas requirement

Example of typical oxygen concentration module used in ozone contacting systems designed for high ozone concentration and/or high ozone output.

may be met with clean, dry, compressed air. More demanding applications may require that higher concentrations of oxygen be supplied to the ozone generator. Most often this is accomplished through an oxygen concentrator or bottled oxygen collected from the atmosphere.

In all cases, care must be taken to remove compressor oil, water and other contaminants from the feed gas. Removal of moisture is especially important, as it may short out the reactor cell of corona discharge-based ozone generators or cause the formation of corrosive nitric acid. Both conditions will harm the ozone reactor cell. Compressed air is typically collected in a feed air receiver tank, and passed through a coalescing filter (to collect and remove droplets of oil and water), a desiccant (to remove water vapor) and a particulate filter.

The composition of normal, dry air is 20.95% oxygen, 78.09% nitrogen and less than 1% argon, carbon dioxide and other trace gases. Oxygen concentrators remove nitrogen and residual water vapor by the cyclical processes of adsorbing and desorbing nitrogen via a synthetic molecular sieve material. Nitrogen is adsorbed to the sieve material at elevated pressure. Depressurization desorbs the nitrogen and regenerates the adsorbent for the next cycle. Commercial oxygen concentrators sequentially pressurize and depressurize multiple beds of adsorbent to produce a continuous stream of concentrated diatomic oxygen (up to 95% O_2).

Continuous application of poor-quality feed gas to the oxygen concentrator can contaminate the adsorbent with water and oil droplets. Over time, such contamination gradually decreases the oxygen concentration of the feed gas that is delivered to the ozone generator. Ultimately, this reduces ozone output from the ozone generator.

Ozone Generation

Ozone is created when diatomic oxygen is exposed to an electrical field or UV radiation. For commercial processes, ozone is typically generated by corona discharge reactor cells in which diatomic oxygen is flowed though a high-voltage electric field produced between conductive and dielectric surfaces. Corona discharge can produce moderate to high concentrations of ozone (typically 3% to 8% by weight) over broad ranges of output. Ozone generators based on UV radiation typically produce relatively small amounts of ozone at low concentration (2% by weight maximum).

The ozone concentration and total ozone output from an ozone reactor cell are functions of three parameters:

- Oxygen concentration of the feed gas;
- Voltage potential applied across the reactor cell; and
- Flow rate of the feed gas through the reactor cell.

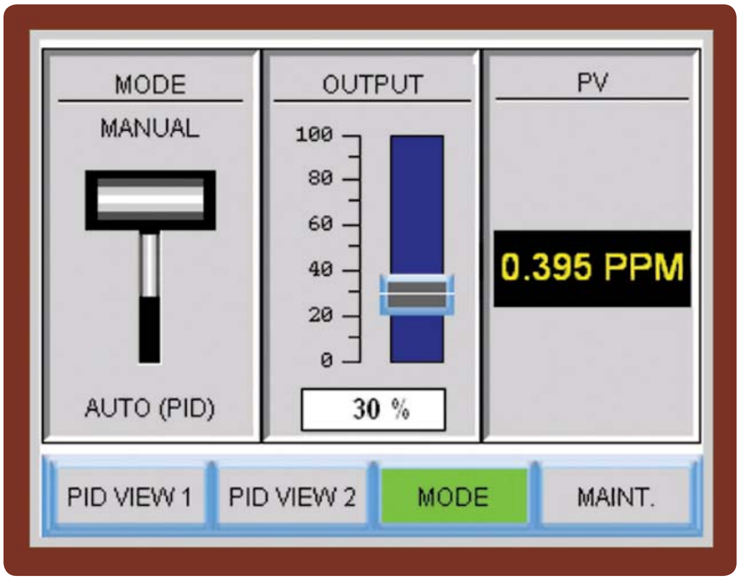
Generally speaking, ozone concentration (percent by weight) can be increased by higher oxygen concentration feed gas, higher voltage across the reactor cell and lower feed gas flow rate through the generator. Ozone concentration and output (grams per hour or pounds per day) may be optimized by adjusting these parameters.

Mass Transfer

Ozone mass transfer—the process of dissolving the ozone gas into solution—may be achieved by bubbling ozone gas through a column of water via diffusion stones or by aggressively mixing the ozone with the water using a venturi injection system. When ozone was first applied to drinking water disinfection and other applications, diffusion stones were the primary method of ozone mass transfer. Today, sophisticated venturi injection systems are often the method of choice for ozone mass transfer over a broad range of application types and sizes.

A venturi creates negative pressure, or vacuum, by accelerating the liquid through a narrowing constriction in a pipe or tube. The pressure in the pipe at the constriction point is lower than in the other portions of the pipe. The passage of a high-velocity water stream across the gas inlet port creates a partial vacuum, resulting in gas suction. The amount of vacuum created by the venturi system is a function of the velocity of the process water running through the venturi. The higher the water velocity, the larger the pressure drop, causing an increase in suction capacity.

A basic venturi injection system consists of a venturi injector, a pump (to drive process water through the venturi) and an off-gas vessel. The off-gas vessel receives the ozone-injected water downstream of the venturi system and collects undissolved ozone gas in the head space of the mass transfer vessel. An advanced venturi injection system consists of a venturi injector, a rapid mixing device, a degas separator and a back-pressure device or nozzle to rapidly transfer the ozone gas into solution under pressure. The excess gas is then discharged through an ozone destruct device. This device contains a bed of heated catalyst that converts ozone back to diatomic oxygen, which is then safely vented to the atmosphere. The components and operating conditions of the venturi system must be optimized to meet the needs of each



Example of a PID control system touch screen for an ozone contacting system on a bottled water filling line.

application. A well-designed venturi system will transfer up to 98% of the ozone gas into solution.

Monitoring & Control

Monitoring and control of ozone generation and contacting runs the gamut from a few simple knobs on the generator control panel to sophisticated closed-loop, PID-controlled systems accessed through touch screens. The type and level of system control required are determined by the requirements of the application.

Most corona discharge ozone generators provide controls for feed gas input flow rate, ozone reactor cell voltage and the flow rate of the feed gas through the reactor cell. These controls are generally sufficient for straightforward applications such as surface sanitization in processed food packaging or disinfection of wine barrels.

Applications that demand tight control of ozone concentration require well-designed closed-loop control. Ozone dosing in final filling of bottled water is a good example of an ozone application requiring sophisticated control of all aspects of the ozone contacting system. Such applications require process feedback, typically in the form of amperimetric detection of the concentration of dissolved ozone in one or more locations in the process stream. Other process feedback might include process water flow rate and temperature, valve position sensors and filler status.

The process feedback is input into programmable PID controllers that continually compare the actual measured values of the monitored parameters with their target values or set points. The differences between these values are input into control algorithms that return changes to the values of the control parameters. Over time, a well-designed PID controller will eliminate the difference between the set point and actual values of critical control parameters.

One Bite at a Time

The answer to the age-old question of how to eat an elephant is germane to the challenges of forming successful ozone systems. What might first be perceived as daunting and complicated can be readily managed when broken into the bite-sized pieces of the basic elements of ozone. Mastering the fundamentals of ozone is a critical first step in the journey to a complete and satisfactory outcome. *wqp*

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