Ozone Injection -
a Superior Choice for
Clean-In-Place (CIP) Applications

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Introduction to Ozone CIP

Compared to manually initiated cleaning or disinfection of fluid handling systems, automated disinfection processes known as Clean-In-Place (CIP) have clear advantages--especially in terms of repeatability, reliability, reduced downtime, and in documenting cleaning performance. When ozone is used instead of chemicals such as hydrogen peroxide or chlorine, even greater advantages become apparent. Ozone is generated as needed at point-of-use (POU), eliminating the need for chemical storage and handling. In addition, ozone breaks down into harmless oxygen without assistance, so there are no worrisome chemical residuals to neutralize.

Where periodic sanitization is required, Ozone CIP Systems economically generate ozone for cleaning beverage plant piping systems, fillers, and related equipment. CIP is an essential production tool that can save companies "thousands of dollars" in operating costs and downtime. The superiority of automated ozone CIP systems is demonstrated in three main areas:

- *Faster disinfection due to the high oxidation power of ozone*
- *Reduced operating costs*
- *Repeatable and reliable chemical treatments*

First and foremost, ozone CIP is the most powerful of the commonly used drinking water oxidants. This translates to faster disinfection times. As shown in **Table I** below, ozone excels by a wide margin in relative oxidation power (destruction capability) over chlorine. In particular, oxidation of organics may be important to some applications. Ozone excels over chorine in this attribute, too. Chlorine oxidation by-products, such as chloramines, can sometimes create further water quality problems. Employing ozone instead of chlorine greatly reduces the potential for this type of problem.

Table 1: Relative Oxidation Power of Various Oxidizing Species

Species	Oxidation Potential (Volts)	Relative Oxidation (Power *)
Ozone	2.08	1.53
Hydrogen peroxide	1.78	1.31
Hypochiorite	1.48	1.09
Free chlorine	1.36	1.00
Hypobromite	1.33	0.98
Chlorine dioxide	0.95	0.70

*based on chlorine as reference (= 100)

SOURCE: Water Quality Association Ozone Task Force. 1997. *Ozone for Point-of-Use, Point-of-Entry, and Small System Water Treatment Applications: A Reference manual* Water Quality Association. Lisie, IL, 2 - 4.

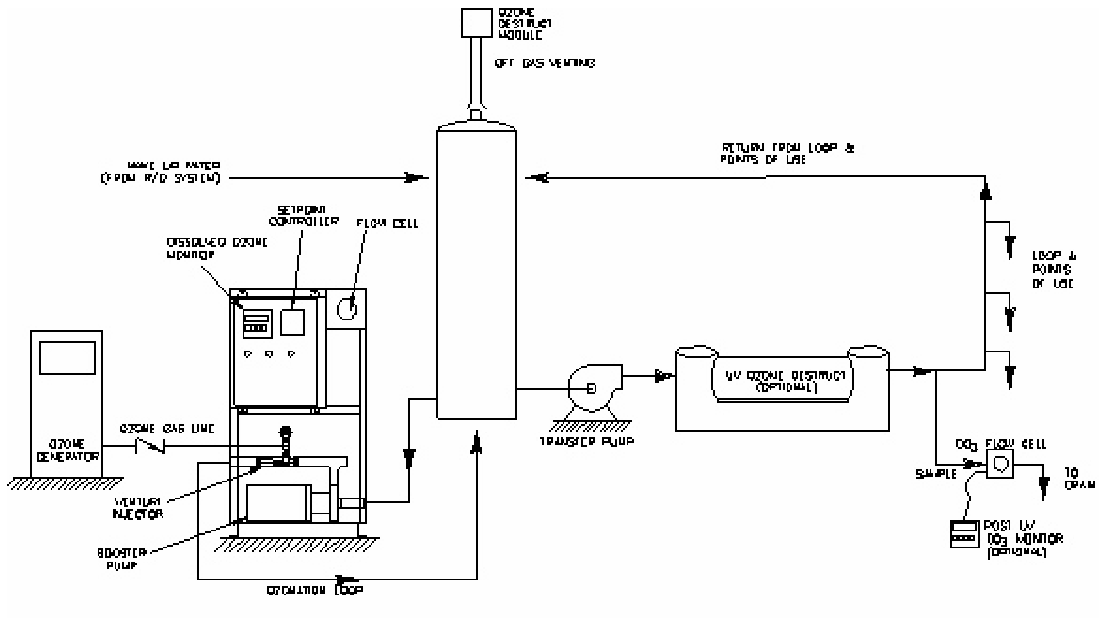

Figure 1: *Typical CIP Ozone System Flow Schematic*

Secondly, use of ozone CIP reduces operating costs. Ozone reduces overall chemical costs, the need for waste water neutralization, and the need to generate steam for heat sterilization. This is particularly important if ultrapure water is used for rinsing, or if solvent wastes have to be incinerated. An ozone CIP system generates ozone on site only as needed - eliminating the need for handling and storage of conventional disinfectants. Some electronics plants have reported increased profits because less plant downtime is now required to disinfect.

Finally, with ozone CIP, each cleaning program is identical to the previous one. This repeatability easily translates into reliability. The rapid adoption of CIP methods in the beverage, pharmaceutical and biotechnology industries is due, in part, to the stringent validation requirements of the US Food & Drug Administration (FDA).

Conventional processes such as steam sterilization exhibit a great degree of treatment variability. Ozone CIP methods, however, can make FDA validations and even
ISO 9000 certification easier to accomplish due to improved consistency and repeatability of treatments
Ozone CIP is so effective that some electronic and pharmaceutical users now apply ozone continuously, at very low levels, to reduce total organic carbon levels of their water.

Principles of Ozone Generation

Ozone is produced when oxygen molecules are exposed to a controlled electrical discharge or corona air within an ozone generator. Oxygen for ozone generation is obtained either by preparing atmospheric air or by using oxygen as a feed gas.

This controlled air or oxygen feed gas stream passes into the generator through spaces known as "dielectric gaps." A dielectric gap is a point where electrical energy is applied, creating a corona arc across this space. Energy applied across this gap is controlled by a high-voltage step-up transformer and is fully adjustable. Assuming constant gas flow and pressure, the amount of ozone produced correlates with the level of energy applied to the dielectric gap.

Once the gas and ozone mixture leaves the dielectric assemblies, it passes through an adjustable flow control valve and then through a check valve prior to exiting the generator cabinet. The cheek valve or optional water trap (with solenoid) prevents the backflow of water into the generator. During ozone production, the corona discharge generates heat. Therefore, the generator utilizes. a cooling water system to maintain a constant dielectric temperature and stabilize ozone output. Without a proper cooling water system, the gas passing through the dielectrics would reach high temperatures, causing the ozone to revert back into oxygen molecules too quickly to allow the target ozone residual to be achieved.

After ozone is produced it must effectively be dissolved into the water to be disinfected. Since ozone has limited solubility (similar to oxygen), more effective techniques are required to optimize the mass transfer of gas into solution. Dispersing the ozone in very small bubbles increases the mass transfer rate from the gas to the liquid phase. Venturi injectors can successfully inject or finely disperse ozone within process water
(see **Figure 1** on previous page).

The most critical aspect of using ozone to disinfect is the ability to carefully control the ozone residual. The Ozone Systems control the ozone residual in process piping by using an advanced dissolved ozone monitor and state-of-the-art Proportional Integral Derivative (PID) control logic. These monitoring and control systems ensure that the ozone level is high enough to effectively kill all organisms, but not so high that certain materials in the process water loop may be degraded.

Principles of Ozone Disinfection

The effectiveness of ozone is best demonstrated in **Table 2** (below) by studying the **C-t^{99}** value, an accepted means of evaluating a coefficient of lethality for various disinfectants. The value of C is the residual oxidant concentration (in mg/L), and the value of **C-t^{99}** is the time in minutes required to kill 99% of the organisms. The **C-t^{99}** value was developed by the EPA for municipal water treatment evaluations, but can easily be applied to other applications like CIP for establishing a minimum disinfectant residual level for target organisms.

The level of ozone residual required for disinfection is disinfection by the type of organisms targeted as well as the overall ozone demand of the water. With the correct operating parameters and ozone dosages, a CIP Ozone System can achieve thorough disinfection--quickly and at lower cost. For example, a typical beverage application may utilize a target ozone residual of 0.2 - 0.4 mg/L in their process piping and achieve disinfection with as little as four minutes of ozone rinsing.

Table 2: C*t Values (mg * min/L) for 99 Percent Inactivation of Micro-Organisms with Disinfectants at 5°C (41°F)

	Disinfectant			
Micro-organism	Free Chlorine (pH 6 to 7)	Preformed Chloramine (pH 8 to 9)	Chlorine Dioxide (pH 6 to 7)	Ozone (pH 6 to 7)
E. coli	0.034-0.05	95-180	0.4-0,75	0.0
Polio I	1.1-2.5	770-3740	0.2-6.7	0.1-0.2
lamblia cysts	47->150	-	-	0.5-0.6
G. muris cysts	30-630	1400	7.2-18.5	1.8-2.0

SOURCE: Hoff, J.C. 1987. *Strengths and Weaknesses of Using C-t Values to Evaluate Disinfection Practice.* Proc. AWWA Seminar, Assurance of Adequate Disinfection, or Cot or not to C-t. Arnerican Water Works Assn., Denver, CO, 49-65.

Effective disinfection is achieved by subjecting the target organism(s) to fixed concentrations of a disinfectant, such as chlorine, bromine, ozone, et al, for a known period of time. When compared to conventional disinfectants, ozone achieves superior disinfection at lower chemical concentrations and within shorter contact periods. For example, chlorine requires considerable contact time to oxidize and destroy micro-organisms. In contrast, ozone oxidation starts immediately upon contact with a micro-organism's cell membrane or wall. Upon oxidation of its membrane, a cell ruptures and its cytoplasm rapidly disperses into the water. Under ideal conditions, continued oxidation by ozone can also convert most of the cell contents into carbon dioxide and water. This reaction can be further enhanced by following ozone treatment with ultraviolet light at a wavelength of 184 nm.

Description of Process

The Ozone Technology AS CIP Ozone System provides a near turnkey approach to CIP methods. The package includes an ozone generator, the injection /mixing device, an ozone monitoring device, and PID controller. A typical CIP start-up and shutdown process contains the following steps:

1. The operator turns the system on manually or remotely.
2. Two solenoids that isolate the injector from the process water are opened.
3. The Venturi injector, powered by a booster pump, draws gaseous ozone from the ozone generator.
4. Dissolved ozone gas is injected into the process water, propelled by the booster pump.
5. The process piping dissolved ozone level increases until the residual reaches a preset limit.
6. Ozonated water in the process piping recirculates until the specified time interval is reached.
7. After the disinfection period is over, power to the generator is shut off manually or remotely.
8. The process piping ozone level drops until the residual ozone gas is purged from the system.
9. The booster pump shuts off.
10. The two solenoids close and isolate the injectors from the process piping.
11. Any residual ozone dissipates and production can resume.

Conclusion

Automated CIP Ozone Systems can save time and money over conventional methods. The higher oxidation power of ozone compared to other chemicals, reduced operating costs, and reliable chemical treatments make automated CIP Ozone Systems a superior choice for process water cleaning and disinfection.

In order to properly size an ozone system for your process, please contact an Ozone Technology AS Sales Engineer or our Application Engineering Department for an Application Questionnaire. Once we quantify such variables as the total volume of plant piping, recirculating flow rates, and the total volume of water in your system, planning your CIP application is easy using automated Ozone Systems from Ozone Technology AS.

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