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# AWT: ADVANCED OXIDATION PROCESS


## Non-Invasive System Has Potential for Deployment Throughout GSA

Between 2014 and 2017, GSA's water rates increased 41 percent. In light of this precipitous rise, GSA's Proving Ground (GPG) has been evaluating alternative water treatment (AWT) technologies that can reduce water use in cooling towers, which are among the largest users of potable water in commercial office buildings. Recently, GPG worked with the National Renewable Energy Laboratory (NREL) to assess an advanced oxidation process (AOP) that works for large as well as small buildings, where there might not be a full-time mechanic or on-site cooling-tower O&M contractor. The AOP technology oxidizes minerals and contaminants in the water, killing bacteria (including legionella) and breaking down calcium buildup to mitigate scaling. Researchers assessing the technology at the Denver Federal Center (DFC) found that the AOP system met GSA water standards, significantly decreased condenser tube fouling, reduced water use by an estimated 26 percent, and delivered a six-year payback, at the DFC water/sewer rate of $7.14/kgal. With normalized installation costs and the GSA average water/sewer rate of $16.76/kgal, payback is achieved in 2 years. The small wall-mounted unit was installed at the DFC in a few hours and can easily be removed, as it does not alter the balance of the chilled-water system. Once installed, the AOP system needed no regular maintenance or monitoring. Based on the successful test-bed evaluation, the advanced oxidation process technology should be considered for all cooling towers.

# INTRODUCTION

**Advanced Oxidation Process Return-On-Investment**

@ GSA average utility costs: water $16.76/kgal, electricity $0.11/kWh

*Normalized installation cost of one unit

| | Baseline (Before) | AOP System (After) |
|---|---|---|
| Installed Equipment (two 250-ton cooling towers)* | N/A | $22,487 |
| Annual Maintenance | $5,855 | $3,333 |
| Annual Water Consumption (gal/yr) | 2,003,273 gal | 1,475,482 gal |
| Annual Energy Costs (5,250 kWh/yr @$0.11/kWh) | $0 | $578 |
| Annual Water Costs (@$16.76 kgal/yr) | $14,303 | $5,457 |
| **Payback (yrs)** | | **2.1** |
| **Savings-to-Investment Ratio** | | **7.2** |

*"We were glad to see that the AOP system performed better than our standard chemical treatment. Over the four years it's been operating, we've continued to see a natural descaling of our condenser tubes and cleaner fill media."*

—Doug Baughman
Energy Management Specialist/OFM
GSA Rocky Mountain Region
Denver, Colorado

## What Is This Technology?

### NON-TOXIC PHOTOCHEMICAL-BASED WATER TREATMENT

The advanced oxidation process (AOP) pulls air from the surrounding environment, which then passes through patented sleeves that contain UV lamps and other proprietary components that modify it, creating a highly reactive mixed-oxidant gas, which contain negatively charged oxygen atoms. The mixed oxidant gas is diffused into the water, forming highly reactive hydroxyl and other free radicals. The hydroxyl radicals and other oxidants help to oxidize minerals and contaminants, killing bacteria, reducing biofilm, and inhibiting scale and corrosion. The dissolved oxidants also combine with water molecules to create hydrogen peroxide, which acts as a long-lasting biocide. With the AOP system, no additional standard cooling-tower water treatment chemicals are required, though a small amount of commercial biocide is occasionally added under special circumstances, such as the accumulation of pollen or other debris in the tower water, which can lead to algae growth. The technology assessed was supplied by Silver Bullet. The AOP system is available in two sizes—for cooling towers up to 400 tons (1,200 gallons per minute, GPM) and for towers up to 2,000 tons (6,000 GPM). The technology can be wall or floor mounted. A gas line with a diffuser is routed from the AOP device to the cooling tower basin; otherwise the cooling tower is left unaltered.

## What We Did

### REPLACED TRADITIONAL CHEMICAL TREATMENT IN TWO-STORY OFFICE/ LABORATORY BUILDING

DFC's Building 95 is a 163,000 $ft^2$, two-story office/laboratory building constructed in 1999. It has two, 250-ton chillers and cooling towers that are exposed daily to sun and wind. In 2014, the DFC installed a non-chemical AWT system in Building 95 that was quickly plagued by algae growth, despite additional biocide treatment. The system was deemed ineffective, decommissioned, and the O&M reverted to traditional chemical treatment. In late 2014, the AOP water treatment system was installed and a new evaluation period began. The primary focus of NREL's evaluation was to measure cooling-tower makeup water use before and after installation of the AOP system. In addition, monthly water chemistry, annual chemical costs, ease of installation, and overall cost-effectiveness were evaluated. NREL used data from the existing metering system and the building automation system (BAS) to characterize the cooling-tower makeup water savings for both the baseline and post-retrofit periods.

# FINDINGS

**26% ESTIMATED WATER/SEWER SAVINGS** The estimated annual cooling-tower makeup water savings are 527,791 gallons/year, with a range of estimated savings from 433,288 gallons/year to 622,307 gallons/year. This corresponds to an estimated total annual cooling-tower makeup water savings of 26.3%, with a lower bound estimate of 22.7% and a higher bound estimate of 29.7%. Blowdown, the water that is periodically discharged to maintain recirculating water quality, was not measured.

**SIMPLE AND NON-INVASIVE INSTALLATION** Installation of the relatively small device (20"h x 15"w x 6"d) took only a few hours, including the simple tie-in process, which consists of connecting the injector hose to the cooling tower basin. The technology does not require internet connectivity to operate.

**IMPROVED CHILLER OPERATIONS** AWT technologies have the potential to decrease energy use by reducing scale and biofilm, which negatively impact heat-transfer efficiency. A borescope view of the two chiller tube condenser bundles, captured after the system had been running for more than two years, revealed a significant decrease in condenser tube fouling from the baseline chemical treatment, though energy savings were not assessed. Each unit draws 396 watts per hour, 24/7, which increased site energy costs by $1,137.

**WATER CHEMISTRY MET GSA STANDARDS** All of the tower-water chemistry values were within GSA's designated ranges, except for Oxidation Reduction Potential (ORP), which was somewhat lower than the required >300 millivolts. Most water-treatment chemicals were eliminated which significantly reduced the environmental impact of the chiller plant operations. Small amounts of bromine/chlorine biocides were used when there was an accumulation of pollen or other kinds of debris.

**INCREASED CYCLES OF CONCENTRATION** Cycles of Concentration (CoC) compares the concentration of solids in the blowdown water to the concentration of solids in the make-up water. The more solids in the water, the higher the CoC. Typical CoC for GSA facilities range between 3 and 6. For 2017, the annual average CoC was 9.54. Modeling indicates that the majority of potential cooling-tower water savings are achieved by a CoC of 10.

**SIGNIFICANT REDUCTION IN O&M** The new cooling-tower O&M contract for the AOP saved the site $2,522 per year, due to reduced chemical expense and a 50% reduction in annual O&M hours. Before the AOP system was installed, maintenance of the cooling tower water required 52 hours annually from O&M staff and $252 per month for the chemical treatment service; the AOP system required 26 O&M hours and $167 per month for the service contract.

**2 YEAR PAYBACK AT AVERAGE GSA WATER/SEWER COSTS** At the combined water/sewer cost in Denver of $7.14/kgal ($4.82/kgal for water and $2.32/kgal for sewer), payback for an AOP retrofit was 6 years, with a Savings-to-Investment Ratio (SIR) of 2.3. At GSA's average water/sewer cost of $16.76/kgal and normalized installation costs, the retrofit payback would be 2 years, with an SIR of 7.2.

**CONSIDER FOR ALL COOLING TOWERS** The simplicity of this product, its ease of installation, reduction in water and onsite chemical use, and positive ROI make it a good candidate for future AWT deployments.

# CONCLUSIONS

These Findings are based on the report, "Demonstration and Evaluation of an Advanced Oxidation Technology for Cooling Tower Water Treatment," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

*Technology reviewed in this test-bed measurement and verification was provided by Silver Bullet Water Treatment Company.*

## What We Concluded

**O&M CONTRACTS NEED TO BE UPDATED FOR AWT TECHNOLOGIES**

The advanced oxidation process technology met all success criteria for water savings, reduction in chemical costs, water chemistry, cost effectiveness, and ease of installation at the test location. Modeling indicates that it should be cost-effective across the portfolio. The technology can be leased or purchased, and the cost of the lease, combined with a service contract, is comparable to the cost of traditional chemical treatments. Whether the technology is leased or purchased, O&M contracts will have to be updated in order to transition from traditional chemical treatment to an AWT system.

## Lessons Learned

**COOLING TOWER PERFORMANCE IS LOCATION-SPECIFIC**

Seasonal changes and variables such as ambient air quality can impact performance and contribute to biological growth that might require chemical treatments and additional maintenance. At the DFC, where the cooling towers are exposed to almost continuous sun and wind, biocide was sometimes needed to prevent biological growth when there was an accumulation of pollen or other kinds of debris.

**WATER SAVINGS ARE SITE-SPECIFIC**

Sites in hot/dry climates with low wet bulb design temperatures will typically have the largest savings. Water quality also impacts performance. Locations with excessively hard water, high pH, etc., typically require more water and chemicals, and will have the greatest opportunity for savings. The makeup water at the DFC was not particularly hard, 72 mg/L. The US Geological Survey estimates that more than 85 percent of the United States has hard water (>121 mg/L).

**BIOFILM IN CONJUNCTION WITH SCALE IMPACTS EFFICIENCY**

In addition to scale, biofilms have a significant impact on heat-transfer efficiency. The high-water content of biofilms creates an insulating layer that inhibits energy transfer to a much greater degree than mineral scale alone (due to the high specific heat of water). At the DFC, biofilm was seen before the installation of AOP but not after.

**TWO SYSTEMS INSTALLED, ONLY ONE NEEDED**

Because Building 95 had struggled with algae growth after testing another AWT, site staff chose to install two AOP systems. In retrospect, however, only one system was needed.