After a Decade of Development: A Profile of Municipal Drinking Water Plants Utilizing a Sidestream Injection Process

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GDT PROCESS REVIEW

The technology of rapid ozone mass transfer followed by degasification, the GDT™ Process, was first introduced in 1995 by Mazzei et al. At the time of introduction, municipal ozone installations utilized a low concentration, air-fed ozone gas as a disinfectant in atmospheric contact basins fitted with fine bubble diffusers (FBD). Over the past decade, air-fed ozone has given way to highly concentrated, oxygen-fed ozone. The change to concentrated oxygen feed gas has increased concerns about the corrosive effects of high finished water dissolved oxygen (DO). Water treatment plants using oxygen fed ozone have reported finished water DO levels in excess of 20 mg/L, with some plants resorting to air sparging at the back end of the contact basin to restore finished water to atmospheric gas levels.

However, the evolution to oxygen feed gas has also produced significant cost benefits. Operating an ozone generator on oxygen increases its ozone production; reducing the size and capital cost of the generator needed to meet ozone output requirements. The use of a concentrated gas stream has also led to the development of side stream injection systems, which move the gas mixing out of the atmospheric basin and into the upstream pipeline (Neemann, 2002), resulting in a more compact contact basin design. Municipal water plants not having a CT requirement have streamlined one step further, by eliminating the ozone contact basin in favor of a sidestream injection Process. This paper reviews the technology of the GDT™ sidestream injection process and introduces 2 municipal water treatment plants (WTP) installations utilizing this process to remediate taste and odor compounds and as a method to reduce finished water dissolved oxygen concentrations.

Keywords Ozone, Ozone Contacting, Injectors, Degassing Separators, Sidestream Ozone Addition
variety of operating parameters are utilized to optimize the transfer of ozone to solution prior to degasification (Figures 3 and 4).

Design circumstances, which may require the utilization of the sidestream injection process, are numerous; two of the more common are (Overbeck et al., 1996; Jackson et al., 1999):

1. Concern with pipeline suitability for ozone gas contacting; and
2. A desire to reduce finished water dissolved oxygen saturation.

The sections that follow provide a brief review of two recent municipal ozone installations that utilize the GDT process for ozone mass transfer and off-gas control.

CITY OF WICHITA: DESIGN-BUILD OZONE SYSTEM

Introduction

The City of Wichita’s design-build ozone installation at the Cheney, Kansas reservoir is, by all accounts, a huge success. Consumer complaints of the Geosmin and MIB generated taste and odor compounds have disappeared. Ozone microflocculation of the organically rich Cheney reservoir water allows the municipality to comply with the 0.30 NTU turbidity limit, specified by the 1999 USEPA Interim Enhance Surface Water Treatment Rule, with a minimum use of a dwindling ground water supply.

The Design-Build Process: Pilot Plant/Bid Spec Design

In the summer of 2003, the GDT Corporation was contacted by the engineering firm, Black and Veatch, with a request for a GDT ozone transfer and degasification skid for use in an on site pilot study that would determine the ozone dosage needed to remediate the taste and odor problems at Wichita’s Cheney pump station, located at the reservoir in Cheney, Kansas.
The study determined that an applied ozone dosage of 5 mg/L was required to remediate the reservoir’s projected peak taste and odor compounds. By November of that same year, Black and Veatch designed the ozone contacting system for the 60 inch, 21-mile long pipeline, that would carry the ozonated reservoir water to the City of Wichita’s filtration plant (Figure 5).

The design called for two sidestream injection and degasification trains, using a post-treatment pump boost of the highly ozonated water out of the degas separator and into the pressurized, 80 MGD pipeline flow. The post boost design was selected over the standard pre-injector pressure boost because it offered the lowest operating horsepower, allowed the plant to control the injector outlet pressure by changing pump speed and isolated the injector and separator from potential, pump generated, vibrations.

The design-build bid specification for the Cheney pump station ozone system was on the street by January 2004 and a month later was awarded to the team of Utility Contractors, Wichita, Kansas and Earth Tech, Sheboygan, Wisconsin, with Ozonia North America and GDT selected as vendors to supply the ozone generation and transfer system.

The Design-Build Process: Design Modifications

The ozone system design team, Earth Tech, Ozonia and GDT, had several concerns about utilizing the specified post – pump, side streams; two primarily being the nineteen foot height of the degas separators and the effect that would have on building height. The other concern was the corrosive effect that a supersaturated dissolved ozone stream would have on the post separator pressure boost pumps. Obtaining 316 stainless steel pumps with hardened Teflon seals came at a high cost, with no guarantee from any pump manufacturers that their pump would stand up to the better than 35 mg/L dissolved ozone expected in the degas separators’ effluent.

The ozone system design team initially considered using direct injection of the ozone gas into the pipeline via a Mazzei Injector Pipeline Flash Reactor (U.S. Patent No. 6730214). The dissolution of ozone in the full flow Flash Reactor would allow for the use of a pre-injector, standard fitted pump, at a reasonable horsepower. However, it was later determined that the direct injection of ozone gas would result in some high pressure losses along the pipeline and had the potential to cause accelerated corrosion of some pipeline materials.

The team ultimately selected the use of four smaller GDT sidestream transfer and degasification contact trains, each using a pre-injector boost pump to create the side stream flow and the injector pressure differential required to develop ozone gas suction (Figure 6).

The re-design of the GDT sidestreams involved a trade off in the type of risk we were willing to accept in the construction of the ozone injection system. Placing the pumps in front of the injectors allowed the design team to sidestep the risk of pump or pump seal failures caused by exposure to excessive ozone concentrations; however, it introduced considerable risk with regard to the performance of the ozone gas injectors, by requiring the team to operate the ozone injectors at operating pressures far exceeding their know design and performance.

The Design-Build Process: Extrapolation to the Unknown

Early in our design discussions, Earth Tech presented new information on the ozone injection site’s pipeline
pressures. Based on their calculations, it was determined that the pipeline pressure would be 90 psig at a maximum flow of 72–74 MGD, not the 70 psig pressure at the 80 MGD pipeline flow outlined in the bid specification.

To stay within the flow range of the smaller degas separators and maintain injector gas suction at the higher pipeline pressure, GDT selected a smaller Mazzei injector than originally specified. The injector would be required to operate at a very high inlet pressure, more than 4 times it’s published operating pressure; at a peak flow velocity exceeding 150 feet per second through the venturi.

To determine the required inlet pressures, water flow rates and gas suction performance under the high-pressure conditions, the team asked the Mazzei Injector Corporation to provide a projection of the injector’s performance. The projection indicated that the injector had a high probability of meeting the GDT gas mixing requirements.

However, Mazzei Injector could not provide a injector performance table, due to the absence of performance test data under the extreme pressure conditions specified by the Cheney design team. In retrospect, the team should have directed Mazzei to pilot the selected gas injector at the expected high-pressure conditions; however in our effort to finish the project on time, we proceeded to install the ozone injection systems, relying solely on the projected performance.

CHENEY SYSTEM START-UP: MEASURED INJECTOR PERFORMANCE

System start-up began in April 2005. Within a few weeks it became apparent that the ozone injectors would not provide full gas suction capacity at peak plant flows and pressures. With considerable assistance from the ozone system supplier, Ozonia, GDT and Mazzei Injector worked to optimize the gas capacity of the ozone injectors.

In September 2005, after several months of adjustment to the gas feed system and considerable performance analysis, it was concluded that the injector gas suction capacity would fall short by 20–25%. By that time, the Mazzei Injector Corporation had transitioned from injector supplier to a full member of the Cheney design team. As a design team member, Mazzei offered to develop and pilot test a high pressure version of the ozone gas injector.

A new prototype injector, 6094-HP, was installed on the No. 2 sidestream injection train on November 15, 2005. Initial testing showed it would provide up to 90% of the peak ozone design dosage of 5 mg/L, at a peak plant flow of 74 MGD. Following several months of continuous operation, three additional 6094-HP injectors were installed to complete the change over to the custom 6094-HP injectors. Recent testing of the ozone injection system showed that the Cheney GDT side stream injection systems will provide better than 90 % of the plant’s peak ozone design capacity.

CHENEY SYSTEM INSTALLATION: A WORK IN PROGRESS

Because the ozone dosage was set for potential peak taste and odor conditions, the plant was able to produce very acceptable tasting water at less than peak ozone feed rates. The City of Wichita enjoyed great tasting water utilizing the standard injectors, which, per mass flow meter readings, were providing only 75% of the design ozone dosage. The city will continue to enjoy great tasting water with the custom 6094-HP injectors, which operate at a much higher gas suction capacity under high pressure conditions; providing up to 91% of the design ozone dosage (Oneby et al., 2005).

The Cheney ozone system design team continues to make improvements to the plant operation, while the City of Wichita enjoys exceptional water quality provided by the only municipal high-pressure sidestream ozone transfer and degasification system in North America (Figure 7).

CITY OF KISSIMMEE, FL: DESIGN-BUILD OZONE SYSTEM

Introduction

While the Cheney ozone system design team was learning the difference between the terms, “projected performance” and “measured performance,” the City of Kissimmee, FL was piloting ozone at their Toho well site, under the direction of the engineering firm, Malcolm Pirnie.

The Mazzei Injector Corporation was asked to provide a GDT ozone pilot skid to determine the applied ozone dosage required to oxidize hydrogen sulfide (H\textsubscript{2}S) from
the 5 MGD water system. Based on initial water analysis, it was estimated that the peak ozone dosage would range from 7 – 10 mg/L (Figure 8).

**City of Kissimmee: Toho WTP Ozone Pilot Study**

The pilot system was designed to use the GDT\textsuperscript{TM} process as a sidestream contactor and degasification system. Limitations on the pilot plant’s pipeline size minimized the water available for pilot testing, consequently the pilot ozone generator, capable of producing a 10% wt ozone gas stream, was turned down to operate at a 5% ozone gas concentration to keep the applied ozone within the expected dose range.

The pilot plant’s utilization of a high applied ozone dosage at a low ozone gas concentration, significantly increased the size of the GDT sidestream required to transfer the ozone gas to solution; resulting in the pilot plant operating with a 60–70% sidestream (Figure 9).

**City of Kissimmee: Pilot Plant Dissolved Oxygen Concerns**

Pilot-plant operation confirmed that an ozone dosage of up to 7.2 mg/L was required to remediate the current sulfide ion (S\textsuperscript{2–}) concentrations; system design dosage was set at 9 mg/L.

Reports by other municipalities utilizing oxygen fed ozone indicated that the finished water could have up to 20 mg/L dissolved oxygen (DO) potentially causing excessive corrosion in the water distribution system and requiring a post ozone oxygen stripping/sparging system.

To ensure that their design would minimize finished water DO levels, Malcolm Pirnie conducted additional analysis on the GDT sidestream pilot setup, utilizing a pure oxygen gas flow (ozone percent gas concentration at 0% wt), to determine worse case, finished water dissolved oxygen concentrations. At all (ozone) pilot gas flow conditions, finished dissolved water oxygen concentrations remained ≤13 mg/L. Using their dissolved oxygen measurements as a baseline number, it was calculated that the full-scale ozone plant could operate with a finished water dissolved oxygen concentration ≤11 mg/L, by utilizing an ozone gas concentration ≥10% (wt) and operating with a side stream ≤50% of the well site’s peak flow rate.

**City of Kissimmee: Plant Start-Up and Operation**

Exactly 1 year from the week of the ozone pilot, the Toho WTP was ready for start-up. The plant consists of two 400-ppd Fuji Electric ozone generators, operating at 10–11%, and two GDT sidestreams, along with the standard ozone instrumentation and off gas destruct modules (Figure 10).

Start-up reports from the ozone system supplier, Fuji Electric, indicates that the ozone injection systems are capable of handling 125% of the design ozone dosage. Water samples taken from a sampling valve, located at the top of a downstream pipeline, indicate that the degas separators are removing the undissolved, entrained gas bubbles discharged by the Mazzei injectors.

The ozone plant currently operates using a sub-stoichiometric ozone dosage (no dissolved ozone residual) to remediate H\textsubscript{2}S from the ground water. Operation with a sub-stoichiometric ozone dosage allows the Toho WTP to oxidized hydrogen sulfide without exposing the downstream pipeline and ground water storage basin to a dissolved ozone residual.
Fine-tuning of the Kissimmee, FL Toho ozone plant is ongoing. Details of the plant performance and finished water DO concentration will be provided in future publications.

REFERENCES


