Mazzei®

CASE STUDY

Ozone to Enhance Removal of Iron and Manganese and Reduction of THM *(trihalomethanes—chloroform, bromodichloromethane, dibromochloromethane, and bromoform)*

Sidestream Venturi Injection—Pipeline Flash Reactor™ Ozone Dissolution System

Vernon C. Russell Water Treatment Plant (Danvers and Middleton, Massachusetts, USA)

The Problem: The 7.5 MGD Vernon C. Russell WTP is the primary drinking water source for the 33,000 residents living in the towns of Danvers and Middleton, Massachusetts. Constructed in 1976, the treatment facility operates at an average flow of 3.2 MGD, with raw water supplied by three surface water and two ground water sources.

In 2006, the US Environmental Protection Agency's (USEPA) promulgation of the Stage 2 Disinfection By-Products Rule required Danver's Public Works Department to establish a Two-Phase upgrade of the plant's treatment process in order to comply. Phase I of the upgrade switched the plant's disinfection process from Chlorine gas to Chloramines, to help meet the newly set THMs maximum concentration limit (MCL) of 80 ppb. Phase II was an extensive upgrade which included the replacement of aging equipment and the addition of ozone to enhance the removal of iron and manganese and to further reduce THMs through the oxidation of THM precursors.

The Solution for Phase II: The ozone system design included a pre-filter oxidation of iron, manganese and THM precursors, and intermediate disinfection. To minimize the ozone system's infrastructure footprint, the design team decided to use sidestream Venturi injectors (SVI) with a Pipeline Flash Reactor (PFR) for ozone dissolution instead of a conventional fine bubble diffusion contact basin. The transfer of ozone into the plant's bulk water pipeline flow allowed the design team to minimize the contact basins' footprint and side water depth.

Ozone contacting specifications required that the injection system provide an ozone transfer efficiency (TE) of > 95%. Failure to meet the 95% TE target would require the ozone system supplier to repair or replace the ozone injection system until the ozone transfer target was met.

During the early design phase of the project, the pipeline hydrostatic working pressures for both the pre-ozone and intermediate ozone was set at 20 psig. Later, that working pressure was dropped to 5 psig. Mazzei ozone transfer calculations showed that the gas injection systems would easily meet the ozone transfer target under both hydrostatic conditions.

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The Results: In February 2014, almost 2 years from the award of the project, Mazzei personnel arrived at the project site to assist the Ozone System Supplier (OSS) with class room training and performance testing of the gas injection system. At the time of Mazzei's visit, only the pre-ozone injection system could operate due to permit issues. Consequently the focus was on the pre-ozone system. The class room session emphasized the operating parameters which affected ozone transfer, one of which was the pipeline hydrostatic working pressure. The session included a review of ozone TE at 5 psig and 20 psig PFR working pressures. Following the class room session, utility personnel accompanied Mazzei and the OSS into the ozone equipment building to take a look at their SVI-PFR ozone dissolution system. The plant manager, pointing to the vertical PFR installed just below the contact basins' long sweep elbow and only 2 feet (as Mazzei was to learn) below the basin's outlet weir, asked why, if increasing water pressure improved ozone TE, his PFR was not installed in the pipeline's horizontal run, which lay 11 feet below the contactor's inlet elbow? (FIGURE 1).

FIGURE 1: WTP Pre-ozone PFR

A look at the project drawings showed that, although the installation did not comply with the process design, the shallow water PFR was per project drawings. Mazzei estimated that ozone TE in < 1 psig of water pressure would be, at best, 80% or 15% below the specified ozone transfer efficiency target.

The OSS, Mazzei and plant personnel, prepared for low ozone TE, and commenced testing the preozone gas injection system performance. Testing began at an applied ozone dosage of 5.8 mg/l, but, remarkably, data collected did not conform to expectations (TABLE 1). The remarkably high and unexpected ozone transfer efficiency measured while commissioning the pre- ozone system was likely due to the increased gas solubility in the 36 °F raw water.

Vernon C. Russell Water Treatment Plant Pre-Ozone
Ozone Dispersion System Functional Testing

System Operating Conditions									
	Date	2-Feb-15	2-Feb-15	2-Feb-15	2-Feb-15	2-Feb-15	2-Feb-15	2-Feb-15	2-Feb-15
	Time	09:15	09:21	09:34	09:39	09:51	10:14	10:19	10:26
	Plant Flow, mgd	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Ozone Dosage, mg/L	5.77	5.77	5.77	5.77	5.77	3.38	3.49	5.71
	Ozone Production, ppd	265.00	265.00	265.0	265.00	265.00	155.0	160.0	262.0
	Ozone Concentration, % WT	10.00	10.00	9.72	0.77	10.05	10.00	9.96	9.01
	Gas Flow, scfm	22.10	21.90	22.0	23.00	21.60	13.1	13.3	24.3
Sidestream Injection System Operating Conditions									
Injector No. 1	Injector Gas Inlet Pressure, psig			0.0	0.0			0.0	0.0
	Injector Inlet Pressure, psig			31.5	31.5			31.0	29.0
	Injector Outlet Pressure, psig			5.0	5.0			5.0	5.0
	Injector Flow, GPM			322.0	323.0			323.0	322.0
Injector No. 2	Injector Gas Inlet Pressure, psig	1.0	0.5	0.0	0.0	1.0	0.0		0.0
	Injector Inlet Pressure, psig	32.0	32.0	31.2	31.0	32.0	29.0		29.0
	Injector Outlet Pressure, psig	5.5	5.5	3.0	3.0	5.5	2.0		2.0
	Injector Flow, GPM	315.0	315.0	327.0	326.0	315.0	315.0		323.0
Water Quality Results									
Raw Water	Dissolved Oxygen, mg/L	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Treated Water	Dissolved Oxygen, mg/L	17.45	17.98	18.15	18.05	17.88	17.50	17.20	17.92
Treated Water	Dissolved Ozone, mg/L	0.95	0.96	1.70	1.42	1.15	0.31	0.21	0.57
Ozone Transfer Calculations (Dissolved Oxygen Compensated)									
	Off-gas Ozone Concentration, % WT	0.03	0.06	0.03	0.06	0.14	0.20	0.16	0.03
	Gas Flow Lost as DO, scfm	3.6	3.8	3.9	3.8	3.8	3.6	3.5	3.8
	Gas Flow Out of Destruct, scfm	18.5	18.1	18.1	19.2	17.8	9.5	9.8	20.5
	Ozone into Process, ppd	265	265	265	265	265	155	160	262
	Ozone Out to Destruct, ppd	1	1	1	1	3	2	2	1
	Ozone Transfer Efficiency, %	**99.7%**	**99.5%**	**99.8%**	**99.5%**	**98.9%**	**98.5%**	**98.8%**	**99.7%**

TABLE 1: Vernon C. Russell WTP Ozone Injection & Transfer Data

In May 2015, follow up with the water plant manager confirmed that high ozone transfer efficiency continues at the pre-ozone installation, though he was unable to provide Mazzei with specific ozone off gas numbers. The intermediate ozone system has not been utilized due to control issues. Plant water quality has improved since ozone system start up, with THM's consistently below USEPA's MCL. The plant is currently conducting a pilot study to obtain a permit which will allow ozone to act as the primary disinfectant, followed by the injection of Sodium Hypochlorite as the secondary disinfectant.