Deep Dive Into Data Reveals Powerful Ozone Story

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There's a lot of truth to the adage that knowledge is power—and what's equally true is that many of us don't realize the power that is literally at our fingertips. At Mazzei, we recently engaged in a six-month campaign to study opportunities in the ozone market for our venturi injectors and sidestream injection systems, which have been catching on in ozone installations covering a wide range of configurations and sizes. In many cases, companies like ours would turn to a market consulting firm for an expensive survey of the marketplace and high-level meetings to discuss the firm's advice.

But we wanted to really immerse ourselves in the details of the industry, to understand not just the technology, but how it evolved and how the market's assumptions and beliefs were shaped. So we took a cue from Megan Glover, a former tech executive and founder of 120Water. As a guest on Water We Talking About, the *WaterOnline* podcast I co-host with Adam Tank, Megan suggested water executives take a deep dive into their own data to better understand their markets and customers. And we did.

Treasure

We quickly realized that all the data we needed was within easy reach. We started with our own application engineering database and computational fluid dynamics (CFD) modeling archives. Then came a treasure trove—a massive Excel spreadsheet detailing every ozone installation in the U.S. and Canada since 1940. All 425 of them.

That data bonanza, originally compiled by the International Ozone Association, is an often-overlooked benefit of IOA membership. The IOA also has a library of outstanding white papers and research reports on ozone technology, as well as another pair of invaluable resources: its members and events. Networking through the association has been a critical source of contacts who are very willing to share their expertise, from ozone generator suppliers to consulting engineers, utility operators, general contractors and other decision-makers.

Slice and Dice

The team of six marketing, sales and technical people collaborating on the deep dive project knew the value of ozone for disinfection, thanks to its unmatched oxidation power that is cast over a broad-spectrum which allow specific dosing requirements and extremely short contact time. We were very familiar with the role ozone can play in the instantaneous oxidation of hydrogen sulfide, robust oxidation of taste and odor compounds, staining elements like iron and manganese, contaminants of emerging concern (CECs) such as pharmaceuticals, and more. We were also well-versed, of course, in the effectiveness of sidestream injection systems that combine our venturi injectors, Pipeline Flash Reactors and basin nozzle manifolds to create the necessary contact between ozone molecules and contaminants that exist in the majority of all of our water supplies.

Last, we recognized that our sidestream injection (SSI) systems have been pitted against older fine bubble diffuser (FBD) technology for decades.

What we wanted to understand was how and where SSI systems and FBD systems were being applied. Was there a pattern driven by facts? What could that tell us about assumptions and erroneous information in the marketplace? Where could we target future growth in ozone?

The answers were in there. We just had to slice and dice the data—by date of installation, by size, by technology and ozone generating capacity and associated treatment technologies.

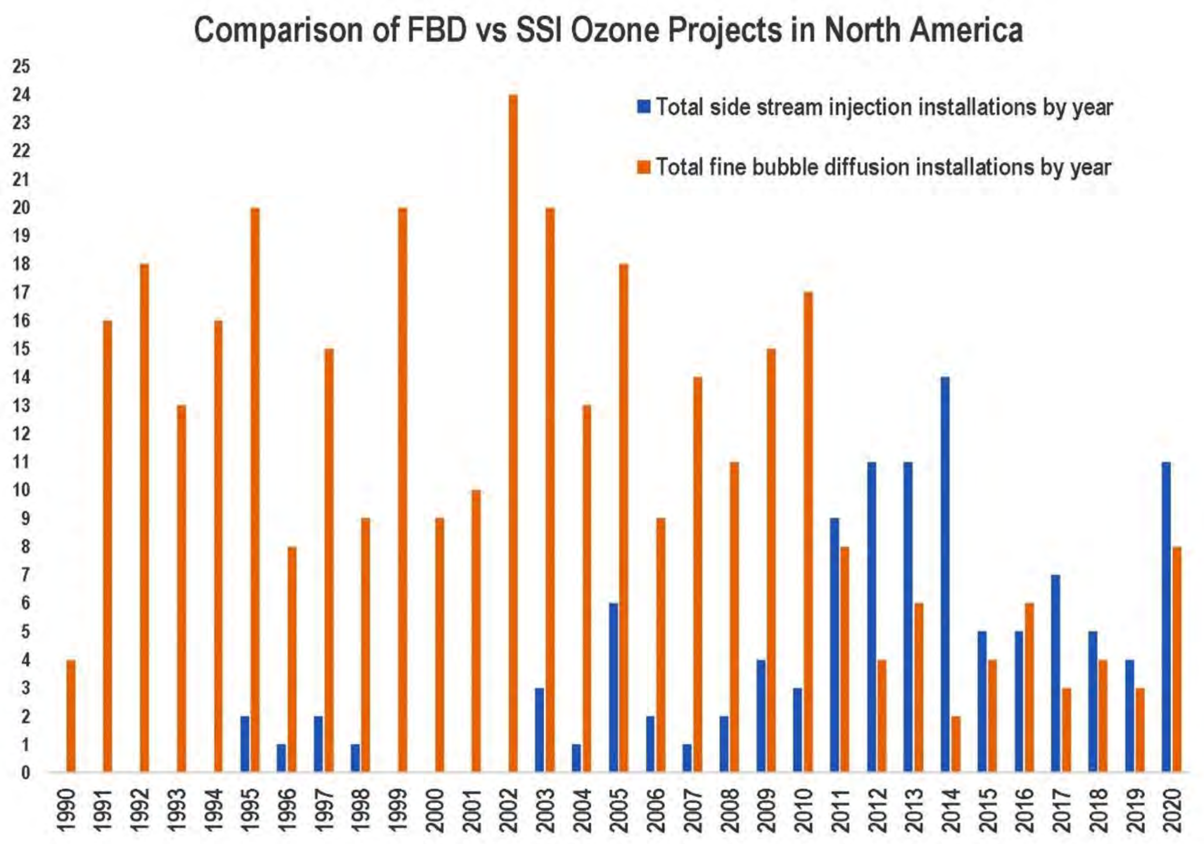

IMAGE 1: Though the first ozone water treatment system in North America was installed in 1940, venturi sidestream injection systems started coming online in the 1990s, when ozone generators were introduced that could produce ozone concentrations of 10% or more.

Time Would Tell

A major variable was the date of installation. Fine bubble diffuser systems date back to the earliest days of ozone water treatment, when ozone generators could produce concentrations of 2 to 3 percent ozone in their effluent gas streams. At such low concentrations, the only viable approach to mixing was to maximize the number of fine-pore diffusers, inundate a huge area with bubbles, and hope for the best.

But by the 1990s, new ozone generator technology could create ozone gas concentrations in excess of 10 percent. Engineers realized that this improved ozone gas generator technology required an improved approach to contacting that did not require the large footprint of passive, diffuser-based systems. This opened the door to other technologies that also provided new and more economic gas dissolution systems.

Venturi injectors became an instant choice for meeting these new operating challenges. Concentrated ozone gas is pulled into the sidestream water flow via the venturi effect, and thoroughly mixed in the highly turbulent outlet cone of the injector. This sidestream two-phase flow is then contacted and mixed with the bulk flow directly in a pipeline or in a contact basin. Downstream of the injector, Pipeline Flash Reactors or basin nozzle manifolds provide intense and complete mixing of the ozonated sidestream back into the main flow to treat water effectively and very efficiently. In particular, the Pipeline Flash Reactors provide as close to plug flow as realistically possible.

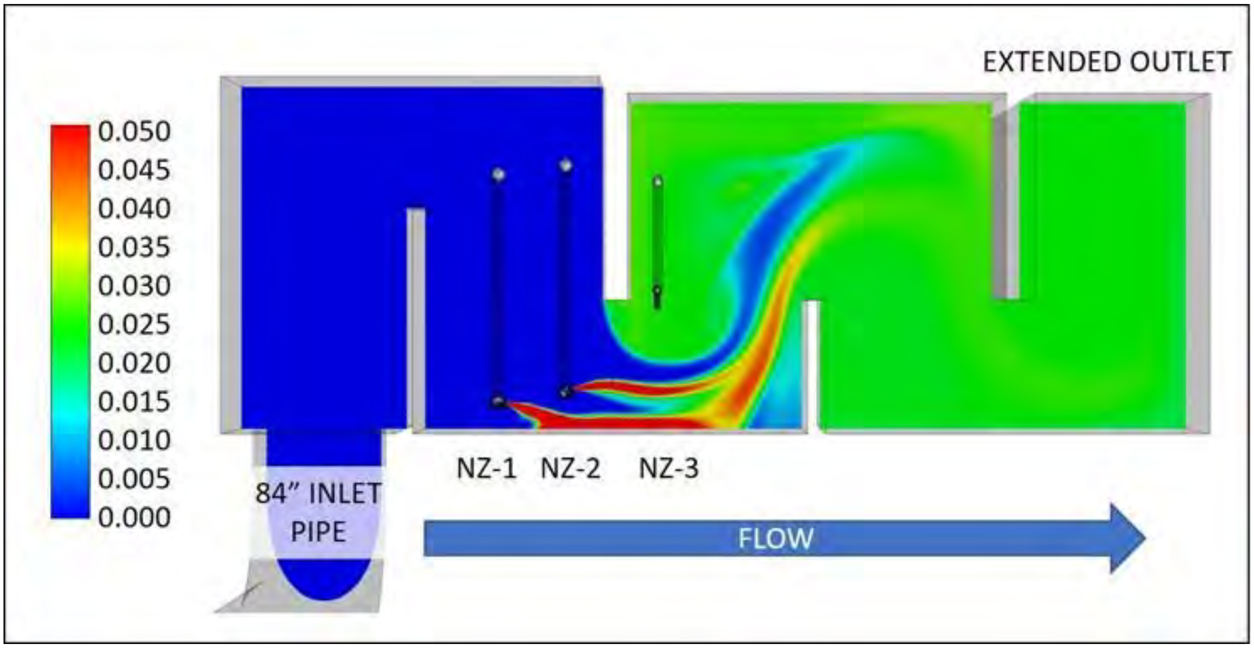

IMAGE 2: Using in-house computational fluid dynamics (CFD), Mazzei engineers have optimized the design and placement of nozzles in their basin nozzle manifold systems to enhance mass transfer and reduce energy demand.

Over the past couple of decades, technology has improved not only the ozone generators, but also the mixing technology. The Mazzei computational fluid dynamics (CFD) team has harnessed the power of computer aided modeling to perfect the design and deployment of mass transfer nozzles in its Pipeline Flash Reactors and basin nozzle manifold systems. This customized engineered solution optimizes not only mixing but does so in the most efficient manner so to minimize energy costs.

The company developed its first Pipeline Flash Reactor™ (PFR) in 2002, which mixes the sidestream back into the main pipeline in just a few feet using specially designed and placed nozzles. In 2013, Mazzei improved on the original PFR design and most recently Mazzei improved on that design and introduced the PFR+, which incorporates precision-engineered flow conditioning vanes and an aggressive, angular mixing grid into the system. The result is an in-line mixing zone that, like the original PFR, occupies just a few feet of space. But it saves more than space as compared to FBD technology; the PFR+ provides significantly greater turn down capabilities without sacrificing mixing performance while reducing the required pressure loss of a traditional static mixer by up to 90%.

IMAGE 3: Angelo Mazzei pictured with a Pipeline Flash Reactor (PFR) at a water treatment plant in Castaic, California (10 – 140 MGD capacity). In just a few feet of pipe, specially engineered and oriented mixing nozzles blend ozonated sidestream into the main flow.

Outdated Assumptions

The challenge we observed by looking deep into the installation data is that many experts in the industry who could benefit from the efficiency and effectiveness of sidestream systems might be operating on outdated assumptions. This technology was well represented in a sweet spot between 10 and 100 million gallons per day (MGD), but many engineers didn't realize that venturi based SSI with modern generating systems would fit larger and smaller plants, too.

By graphing the percent sidestream engineered into various installations, we can point to systems ranging from 42 percent sidestream flow to a preponderance of systems with less than 10 percent sidestream. Operating with such small proportions of sidestream demonstrates the ability of SSI ozone systems to work in plants with flows well in excess of 100 MGD while keeping energy and pumping costs well under control.

The data illustrates the wide range of scale covered by SSI systems, from the 770 MGD Wiley Water Treatment Plant in Texas to dozens of small installations under 10 MGD where ozone is used to control taste and odor compounds.

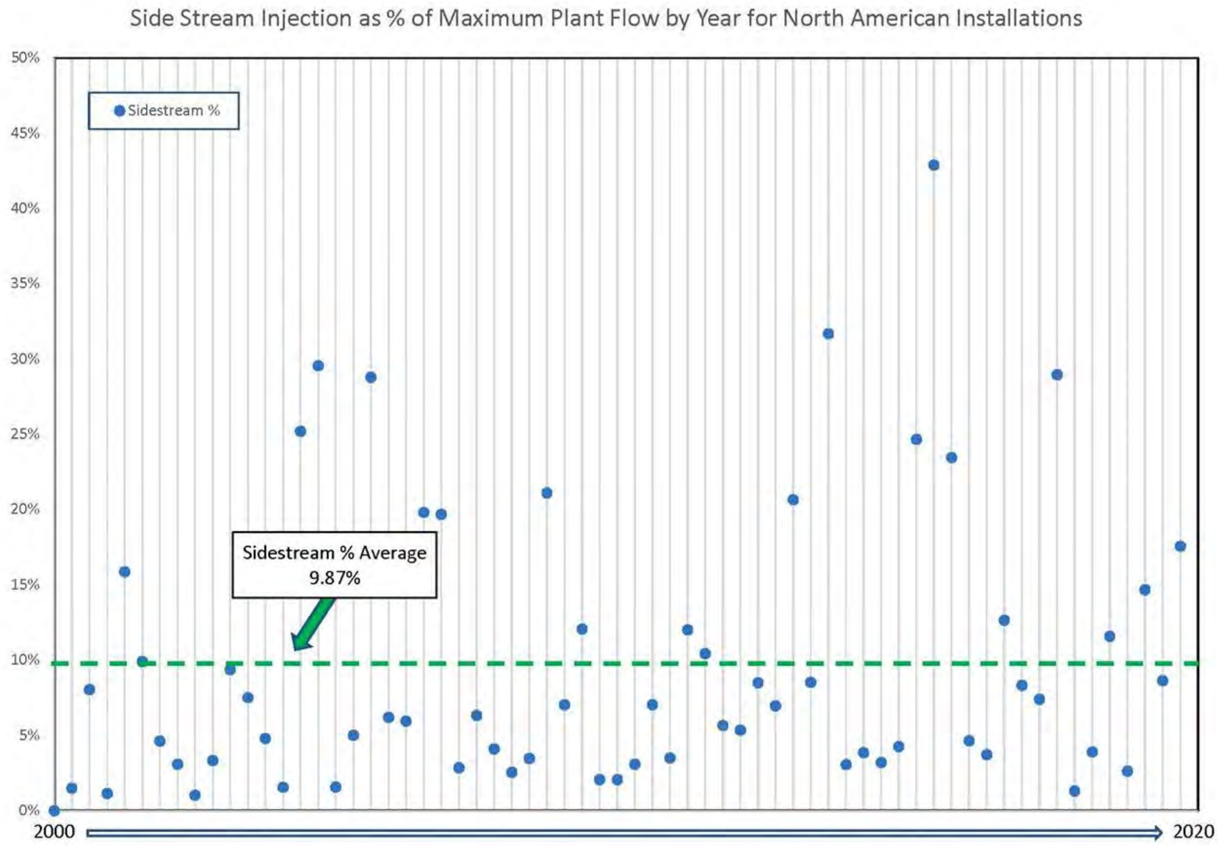

IMAGE 4: Many SSI systems utilize a sidestream of less than 10% of the total flow, minimizing pumping and energy costs. Highly effective mixing technologies mix that small sidestream back into the main flow with remarkable efficiency.

Precision

What the data also revealed was that high-concentration generators, small sidestreams and precision venturi systems walk hand-in-hand with 21st century control systems. Decades ago, clunky control systems, valves and regulators upstream of an ozone system were viewed as an unwanted expense and a hassle. Today, we recognize the value of precise control and improved water quality monitoring that allows targeting of specific contaminants. We celebrate the ability to manage electricity, improve process control and stability, reduce consumption of inputs like liquid oxygen (LOX) or chemicals, and adjust turndown precisely because we acknowledge the need to reduce our costs, target specific contaminants in a small footprint, and improve our accuracy.

Today, careful management isn't seen as a burden, it's an asset. So in short, sidestream injection systems dovetail nicely with the water plants' need for greater control.

The data bears it out. Even 20 years ago, a study by Schulz and Bellamy in *Ozone Science and Engineering* revealed that the coefficient of variation of dissolved ozone residual for SSI systems was 5 percent, dramatically lower than the 20 to 45 percent coefficient of variation observed in fine bubble diffuser systems.

Five percent vs. as much as 45 percent variation. It doesn't take too much imagination or calculation to consider the impact on consumables, or, for that matter, the difference in the potential for excess ozone to form disinfection byproducts like bromate in the presence of bromine. The increase in dose control represented by a 5% coefficient of variation coupled with improved water monitoring techniques allows a plant to fine tune their ozone dosages to their daily / hourly water qualities, essentially eliminating over or under feeding of ozone.

In fact, a 2016 Water Research Foundation study (conducted by several prominent IOA members) compared SSI and FBD systems in the same municipality and found that the SSI plant delivered greater ozone contact and less bromate formation under similar ozone dose conditions. Two pilot trials were conducted: in the first trial, flow was reduced from the original design capacity by 60% and in the second trial it was reduced by 76%. Trial results showed that the FBD facilities produced 5.6 and 9.1 µg/L of bromate at these reduced flows, respectively, while the SSI plant contributed less than 2.0 µg/L of bromate under all flow conditions.

The major reduction in bromate formation from SSI can decrease the need to chemically pre-treat water upstream of the ozone system. That reduces cost, chemical consumption, time, process, storage, handling—a host of challenges posed by the need to preempt a health hazard downstream.

Precision at the ozone dissolutions system also contributes to efficiency downstream. Ozone can blast apart contaminants, oxidizing them into bite-sized pieces for microbes in biologically active filtration (BAF) systems to consume. That is an attractive alternative to conventional filtration systems like reverse osmosis (RO)—which concentrate rather than destroy contaminants—especially when it comes to pharmaceuticals or toxins. It has also been demonstrated that small, controlled ozone dosages upstream of micro-filter or ultra-filter membranes, provide significant advantages to membrane flux and cleaning frequencies.

Precise control of variables including flow, ozone generation, pumping volume and water temperature make it possible to scale SSI systems to large facilities, treating sidestreams of just 10 percent of flow, or less, with outstanding results.

Energy

The ability of today's SSI systems to operate with very small sidestreams and high-efficiency mixing technologies ensures nearly complete mass transfer into the main flow has put another outdated assumption to rest: that sidestream systems are energy-intensive because of the need to operate a sidestream pump.

While that was true decades ago when low applied ozone doses and meager ozone gas concentrations did not merit using a sidestream pump. With higher applied ozone doses and concentrations, there has been a concurrent dramatic improvement in the design and operation of sidestream injection systems. As previously noted, systems with a PFR+ lose less than 1 psi in the mixing stage. Meanwhile, the sidestream pump delivers plenty of energy for mass transfer and mixing, making the most of every joule. A recent success story involves a Mazzei sidestream injection system with Pipeline Flash Reactor that achieved greater than 95% mass transfer at a water depth of only 6 to 8 feet.

The same principle applies in basin nozzle manifolds, where the sidestream pump powers aggressive mixing action in the contactor, driving thorough ozonation with a water depth as low as 12 to 15 feet. Compare that to fine bubble diffuser systems, which require 18 to 25 feet of head to allow for passive dissolution of ozone bubbles into the water—and enough pressure in the line to emit fine clouds of bubbles at those depths. Add to that the transportation and energy needs for more LOX and the lack of flexibility for turndown and the historically assumed energy advantages of FBD systems float away.

Footprint

One of the huge advantages of PFR and PFR+ technology is the small footprint compared to the large contact basins needed for fine bubble diffusers. As a rule, minimum floor coverage for a fine bubble diffuser system is 4 square feet per diffuser, resulting in contactors that the U.S. Environmental Protection Agency reported in 2005 averaged 8 by 18 feet. Though ozone is fast-acting by its very nature, certain applications require more contact chambers to ensure mixing and contact. For instance, *Cryptosporidium* inactivation with fine bubble diffusers requires 10 or more chambers. That is a significant investment in civil works.

Where basins exist already, basin nozzle manifolds downstream of an SSI setup can be a simple, effective retrofit that uses existing infrastructure. However, where space or efficiency are issues, PFR or PFR+ systems can replace the space, engineering and construction required for basins sized to match the main pipeline.

Ozone mass transfer is achieved with a much lower contact time with ozone SSI systems—seconds as compared to minutes in the typical FBD systems—replacing valuable plant real estate with efficiency. With Pipeline Flash Reactors, the efficiency and thoroughness of contacting and mixing is as close to plug-flow as realistically possible.

Maintenance

Networking through IOA has also provided many accounts of the significant maintenance needed for fine bubble diffuser systems. Even in the absence of emergencies caused by blown seals and gaskets or fouled membranes, regular FBD maintenance requires draining basins, closing treatment lines, arduous inspections of each diffuser stone, and putting workers in confined spaces. It takes a lot to keep a fine bubble diffuser system operating.

By contrast, SSI systems have only a single set of moving parts: the sidestream pump. Venturi injectors and mass transfer nozzles are maintenance-free, and sidestream pumps are outside the system for easy access. Between the cost of labor and the losses incurred by having to shut down FBD lines for regular upkeep, the ongoing maintenance of fine bubble diffusers adds up quickly.

According to a 2017 analysis by the American Water Works Association, sidestream injection systems required five fewer days of facility downtime per year than fine bubble diffusers, an advantage that added up to 125 fewer days of downtime and $142,000 less in maintenance costs over the projected 25-year system life.

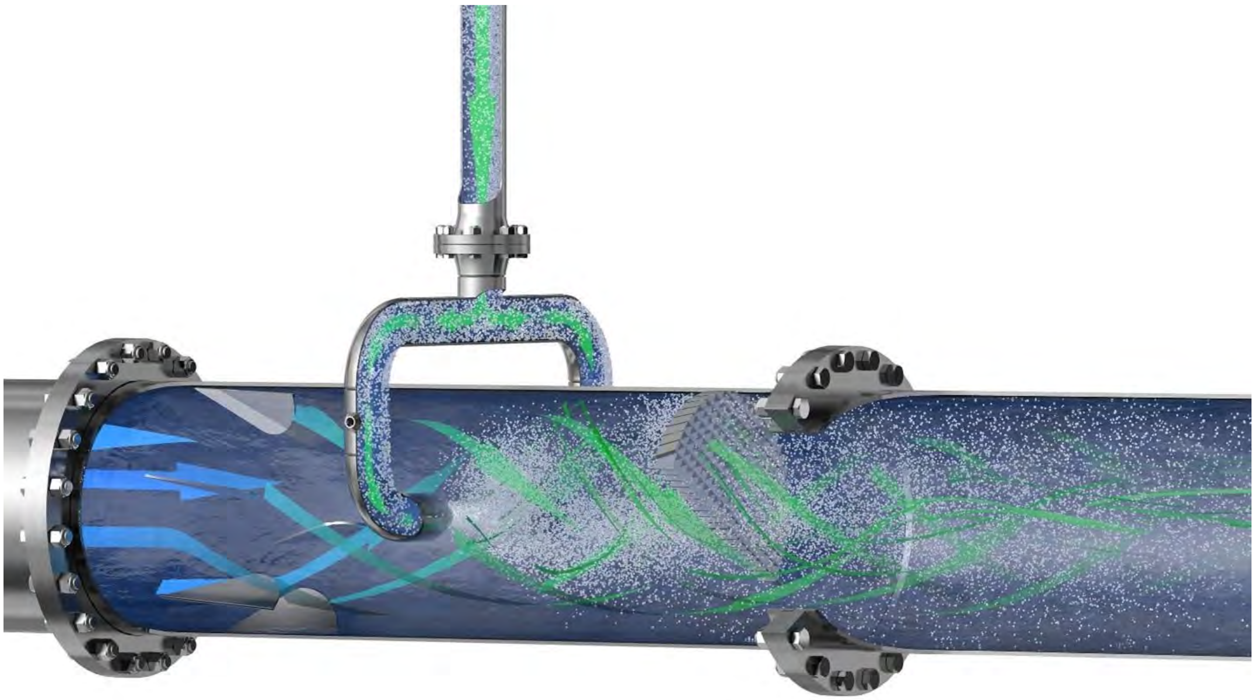

IMAGE 5: Mazzei's PFR+ combines flow conditioning vanes, mass transfer nozzles and an angular mixing grid to maximize contact and mass transfer in just a few feet of pipe.

Collaboration

We have mapped out ways to share what we have learned with colleagues in the industry. That includes detailed information on your company's specific installations, pie charts of ozone sidestream projects by type or spec, and heat maps of particular types of installations. Combined with our in-house engineering and CFD capabilities, market intelligence is another way we can help prospective customers and our colleagues in the ozone industry succeed.

Summary

In terms of the lifetime total cost of ownership, the defining characteristics of Mazzei sidestream injection technology for ozone applications can be quickly summarized as:

1. High turndown capability and operation flexibility without expensive stops to plant operations;

2. High level of applied ozone dose control;

3. Small footprint–a lot less steel and concrete;

4. Energy is utilized efficiently…for mixing *and* mass transfer, not just gas addition;

5. Enhanced hydraulic mixing and gas contacting, tailored for each application with CFD modeling;

6. Very low maintenance;

7. All of the above achieved with typical sidestream flows less than 10 percent of plant flow.

Moving Forward, Together

The easy availability of this not-so-buried treasure of data reminds me of "Acres of Diamonds", a story by Temple University founder Russell Conwell. In short, a wealthy farmer wanders his way to ruin in search of a far-off diamond mine, while the man who bought his farm discovers vast treasure right under his nose. The treasure is right here; all we've had to do is look for it and dig in.