Progressive Color Control: Boynton Beach's High-Rate Fluidized IX System

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Saltwater intrusion continues to exert its influence in Florida's coastal communities. To help protect the surficial aquifer system (SAS), Boynton Beach Utilities (BBU) has taken multiple aggressive steps.

In addition to the installation and operation of two aquifer storage and recovery (ASR) wells, BBU is continuing to shift its utilization of SAS from the eastern to the western wellfield. While this improves the hydrogeological barrier between BBU and the ocean, it comes at a cost. The western wellfield produces lower-quality water than the eastern wellfield, and a significant portion of both the treatment assets, and future growth in demand, are at the East Water Treatment Plant (WTP), which is east of I-95.

The western wellfield, challenged with high organics (up to 13 mg/L total organic carbon [TOC]), high color (up to 59 platinum-cobalt color units [PtCU]), and hardness (up to 292 mg/L), has historically been treated by nanofiltration. While the membrane facility could have been expanded to treat the additional wellfield production, it would have stranded much of the valuable existing East WTP assets. As a result, BBU decided to convey the western wellfield water to the East WTP for treatment; however, the existing plant, a conventional lime softening treatment facility, was not expected to be able to consistently meet a color goal of ≤5 PtCU and would be challenged by disinfection byproducts (due to the high TOC). In order to meet its goals, BBU selected to pretreat with a high-rate fluidized-bed magnetic ion exchange resin process to remove the organics and color, as an augmentation to the existing processes.

The ion exchange system was designed and constructed using a progressive design-build process. The project successfully passed demonstration performance testing in March 2017. Project photographs are included in Appendix A.

New and Improved High-Rate Process

Advancing the state of the science, the design began with what was used for the nearby Palm Beach County WTP No 2. A number of modifications were incorporated to enhance the system, including:

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- Optimized contactor design
- Reduced maintenance and enhanced accessibility
- Advanced system monitoring

Optimized Contactor Design

The performance of the fluidized bed ion exchange system is dependent upon several parameters, including:

- Uniformity of flow distribution through each basin
- Uniformity of resin fluidization and contact time
- Uniformity of resin concentration
- Minimizing resin loss because high rates of resin loss will significantly increase cost of operation

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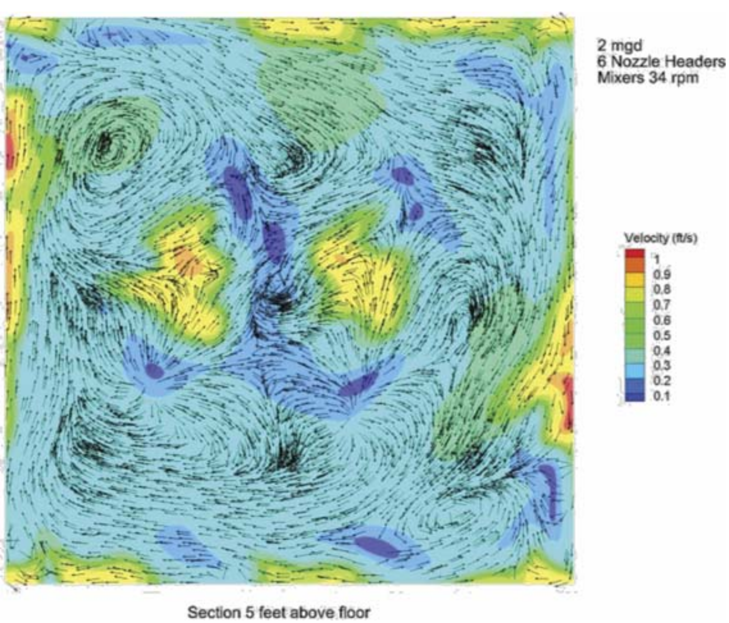

Figure 1. Computation Fluid Dynamics Model Results: Conventional Clockwise Mixers

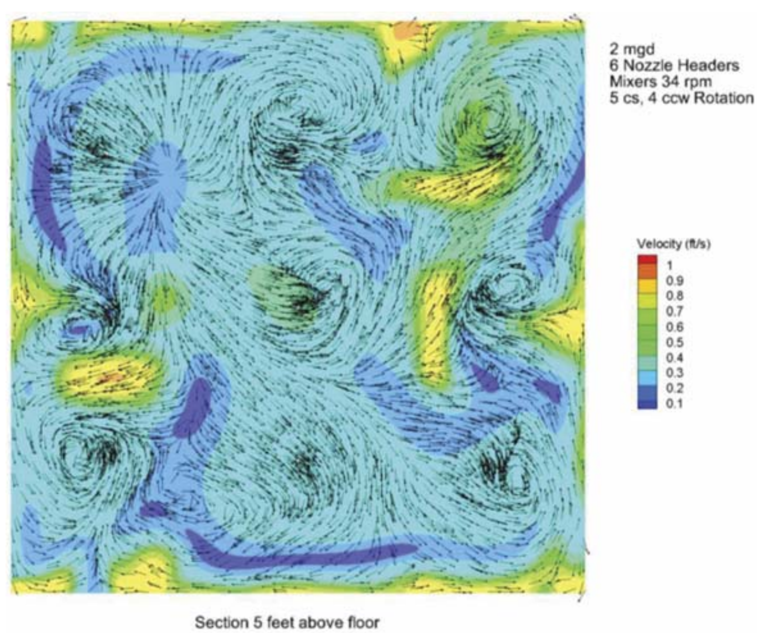

Figure 2. Computation Fluid Dynamics Model Results: Counter-Rotating Mixers

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The contactor was designed to evenly split incoming flow from the west wellfield into the contactor's east and west basins, and each basin was hydraulically designed to treat flows ranging from 2 to 18 mil gal per day (mgd). Flow to each basin is controlled by an inlet-modulating valve and mag meters prior to entering an inlet-stilling chamber that eliminates the potential for air carryover into the resin bed portion of the contactor. Flow from each stilling chamber is distributed into a series of distribution headers and nozzles within the contactor. Each basin has nine vertical shaft mixers configured in a three-by-three grid.

Computation fluid dynamics (CFD) modeling was used to optimize the contactor configuration. All the models had approximately 10 million computational cells, and were used to determine the following:

- *Inlet distribution header configuration.* Minimized head loss through the contactor and distribution headers (sizing) and nozzles (number, configuration, and type).
- *Mixer speed and rotation.* Optimized mixer speed paced by flow, impeller rotation orientation (upflow versus downflow), and integration of stator baffles to allow uniform resin fluidization across the basin.
- *Maximize resin bed usage.* Optimized ion exchange treatment and contact time through maximized resin bed depth and minimized carryover resin loss to the effluent troughs.

The general observation through the CFD studies was that if all mixers were rotating in the same direction, they would create uneven upflow distribution, reduce mixing, and create uneven resin fluidization (leading to poorer performance). Instead, using alternating clockwise/counterclockwise (counter-rotating) mixers better distributed upflow, increased mixing, and provided more even resin fluidization. Representative CFD model results are shown in Figures 1 and 2. Note the significant decrease in the areas of high velocity in the center of the basins by the use of the counter-rotating mixers.

Figure 3. Screenshot of MIEX Basin Control.

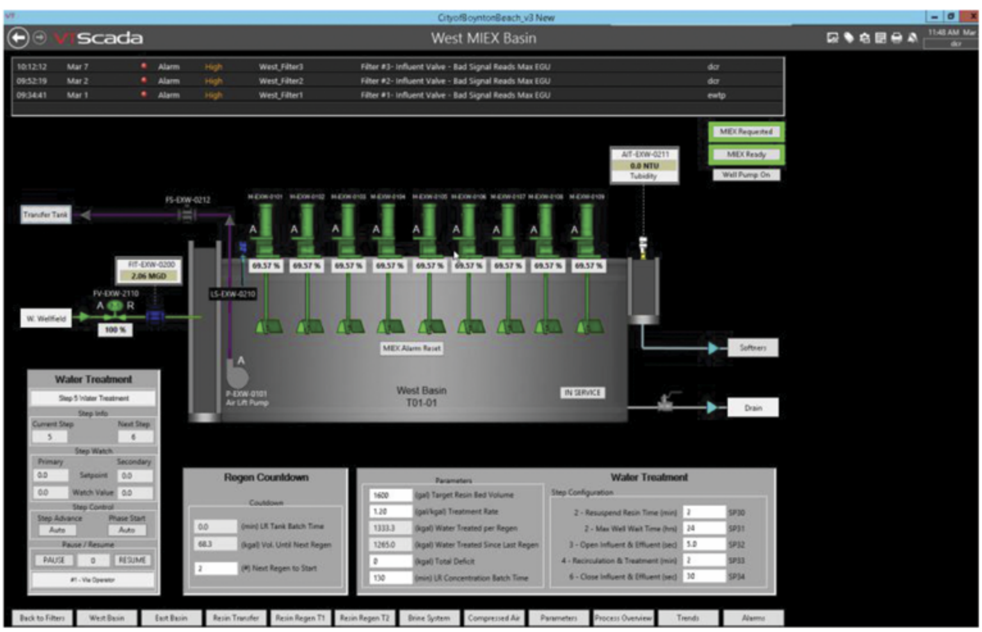

Table 1. Summary of Ion Exchange Performance Testing Results

	True Color	Apparent Color	UV-254	Dissolved Organic Carbon
Raw Water (Average)	41.5 CU	43.1 CU	0.42 cm^{-1}	10.85 mg/L
Reduction (%)				
Minimum	83.7	73.6	77.3	63.2
Maximum	100.0	96.2	94.1	84.7
Average	92.6	84.2	88.8	77.7
Contract Requirement (Based on Average)	>90%		>70%	>60%

Ultimately, the use of counter-rotating mixers without baffle stators was applied to minimize rotation and promote better localized mixing and uniformity of resin fluidization.

Reduced Maintenance and Enhanced Accessibility

While multiple design improvements were integrated into this system for improved resin dosing, resin regeneration, and resin handling, one of the visually prominent differences is the use of inclined plates (instead of tubes) to separate the resin from the treated water. Tube penetrations or larger box-outs for mixer shafts, conveyance of resin, sampling, ladder access, etc., results in hydraulic short-circuiting or dead zones in each reactor's resin separation zone. The hydraulic short-circuiting increases resin loss and the dead zones either decrease the resin efficiency or require higher mixer energy, which in turn increases resin shear/loss.

A modular stainless steel plate pack system was selected to provide sufficient space between the rows of plates to provide the desired access through the resin separation zone, eliminating the inefficiencies caused by tube penetrations and box-outs. Furthermore, the plates are much easier to clean and more resilient than tubes, leading to a significantly longer life and ease of maintenance.

Advanced System Monitoring

A fiber optic data link ties the western wellfield water supply to the East WTP, augmenting the on-site fiber optic network (12-pair/24-strand fiber optic ring). This fiber is the backbone upon which the system's Profibus DP control network runs and feeds the VTScada HMI Control System via a Siemens S7-400 PLC with dual processors to provide for redundancy.

While reducing installation costs through a dramatic reduction in the cost to install control wiring, this fieldbus network provides a richness of data for advanced monitoring of the ion exchange (and other) systems; the ion exchange system alone has 325 input/output points.

This depth of data enhances operation in numerous ways. For example, monitoring the uniformity of the fluidized resin blanket and volume of resin (indicative of resin loss rate) has been traditionally challenging. An electronic depth finder will be installed to measure both the depth and profile of the settled resin surface during maintenance shutdowns, avoiding the need to drain and enter the basin to observe the settled resin (Figure 3).

Results

The ion exchange system has just completed start-up and successful performance demonstration testing, and the BBU staff has recently taken charge of operations. The performance testing showed that all of the water quality parameters are surpassing the specification requirements that were established for the project.

A summary of the raw water quality and performance demonstration testing parameters that were monitored are shown in Table 1.

As a function of the treatment process, there is a small amount of resin carryover from the contactor. The contract specified that the parameter for resin loss is up to 2 gal of resin carryover per mil gal of water treated (g/MG). Measurements throughout the operational testing period demonstrated an average resin carryover of 1.7 g/MG, which was better than the specified requirement.

The benefits of the addition of the ion exchange system have yet to be established on a quantitative or qualitative basis; however, BBU anticipates the following:

- Significant reduction in color allowing optimization of the lime softening process for hardness alone
- WTP capacity increase through use of a softening bypass line
- Significant reduction in disinfection byproducts
- Reduction in lime solids production and reduction in chemical usage

Appendix A: Project Photographs

1. Ion exchange contactor showing inlet header, flow-splitting valves, and magnetic flow meters.
2. Top of ion exchange contactor showing mixer motors and resin transfer tank.
3. Resin regeneration area showing recycled brine tank and resin regeneration skids.
4. Resin regeneration skids.
5. Interior of ion exchange contactor showing mixers and inlet distribution header.
6. Interior of ion exchange contactor showing fresh resin return line.
7. Plate modules inside of ion exchange contactor.