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Meeting Municipal Plant Design and Performance Criteria through Custom Ozone Degas Separator Design.

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Abstract

In the world of municipal water plant design, engineers and equipment manufacturers strive to utilize standard, commercially available equipment and products that come with a pedigree of performance and a history of reliability. The negative consequences tied to poor performance by the specified equipment are financially and politically significant. No municipality wants to act as a multi-million dollar beta test site.

Consequently, the design team for phase II of the City of Wichita, Kansas' Equus Aquifer Storage and Recovery Project (ASR-II) were careful in their selection of equipment for the project's 30 MGD Advanced Oxidation Process (AOP). When Mazzei Injector's GDT TM Degas Separator (degas separator) was selected as the best method for ozone off gas removal, it was based on its many years of successful performance at Wichita's Cheney pump station.

It was with great reluctance that Mazzei Injector informed the engineer that the commercially available degas separator would not meet the project design and performance criteria.

This paper discusses the process of creating a custom degas separator to meet the performance criteria of the ASR-II AOP. Project design and performance requirements, design and performance limitations of the commercially available separator and the design of a custom degas separator are reviewed in detail. Data from test results on the performance of the custom separator, obtained through rigorous testing at the Fresno State University Hydraulics Lab, are presented.

Background

In 1993, the City of Wichita, Kansas developed an Integral Water Supply Plan (ICWSP) that included the ambitious goal of creating a sustainable water supply through the year 2050 (2). The centerpiece of ICWSP is the recharging the Equus Bed Aquifer with 100 MGD of water from the Little Arkansas River (1, 3, 5). The project, City of Wichita's Equus Aquifer Storage and Recovery Project (ASR), began in 1997 with a feasibility study focused on diverting excess river water into the Equus Bed Aquifer. In 2006 Phase I (ASR-1) was completed, diverting up to 10 MGD of river water into the aquifer through bank filtration and recharge basins (2, 6).

ASR-II Design

Keeping the river's organic contaminant concentrations below the US Environmental Protection Agency's (EPA's) maximum contaminant level (MCL) for drinking water was a difficult challenge for ASR-I. Farm land run-off during wet weather events frequently contaminated the river with the triazine herbicide, Atrazine, at concentrations well above EPA's 3 μg/LMCL; forcing the city to shutdown the bank filtration system (6,7).

The limited utility of ASR-I during Atrazine excursions was addressed during the design phase of the 30 MGD ASR-II project. White papers on the topic of Atrazine removal provided many treatment choices, however, after much study, the design team selected an Air Products' Halia™ advanced oxidation system that utilized a multi-stage application of ozone and hydrogen peroxide to provide multi-step advanced oxidation and removal of the herbicide (Figure 1).

$$2O_3 + H_2O_2 \rightarrow 2 \cdot OH + 3O_2$$

Figure 1. Ozone-UV Hydroxyl Radical Formation

AOP Pressure Limitations

To optimize the transfer of ozone, the Halia™ ozone contacting system is designed to mix ozone gas into solution under pressurized conditions. However, the introduction of ozone gas into the pressurized water stream is accomplished without the utilization of sidestream venturi injectors. Consequently, the initial ozone injection stages of the contacting system requires an ozone gas feed pressure that is > 25 psig (8).

The requirement for high pressure gas feed together with the contacting system's design working pressure, limits the amount of downstream backpressure tolerated by the AOP. Downstream hydraulic pressures and frictional losses that elevate the AOP's working pressure beyond design, will prevent ozone introduction into the pressurized water stream. Consequently, when Mazzei was contacted to discuss the removal of entrained ozone gas from the AOP effluent, the hydraulic working pressure of the degas separator was limited to 19 feet.

GDT™ Degas Separator Design And Limitations

A GDT™ Degas Separator is designed to separate entrained gas bubbles from pressurized water streams. The removal of entrained gas bubbles is a two-step process that utilizes centrifugal force and the natural buoyancy of gas bubbles in a column of water. When a water stream containing discrete gas bubbles enters the separator, it is tangentially accelerated into a high velocity spin, similar to the action of a laboratory centrifuge. The centrifugal force created by the high velocity spin, in the range of 4 – 10 times the force of gravity, forms a circulating water film at the separator wall and a central gas vortex (Figure 2). The center of the separator contains a slower moving core of water, called the gas extraction core. The gas vortex drives the bubbles into the core, allowing gas bubbles to collect, coalesce and rise to the top of the separator for release by a pressure relief valve.

Figure 2. Separator Gas Vortex.

The working flow range of a GDT™ Degas Separator is limited. Within a separator's design flow range, it has sufficient centrifugal spin to create a gas vortex that separates gas bubbles from the pressurized water stream. Operation below a separator's minimum design flow results in a low velocity spin without gas vortex formation; turning the degas separator into a gas mixing device. As you increase flow across a degas separator, you increase its internal spin velocity, lengthening the size of the gas vortex down its body. Operation above a separator's maximum design flow, drops the tail of the gas vortex into separator's outlet zone, allowing the outlet to pull a portion of the vortex gas bubbles into the separator effluent.
The ASR-II ozone design criteria called for the use of six (6) GDT™ Degas Separators, each operating at 5 MGD with a maximum 19 feet of hydraulic head or backpressure to the pre-degas AOP system. Table 1I. lists the commercially available 5 MGD GDT™ Degas Separators.

Following a review of the available GDT™ Degas Separators (Table I.), none of which could meet the project's maximum hydraulic pressure requirement, it was suggested that the design team find an alternative method for ozone off gas removal. However, six of the 60" diameter DS-1600 degas separators, which came close to meeting hydraulic head requirements, were considered more cost effective than the proposed off gas alternative, a 300' diameter vessel. Consequently Mazzei agreed to develop a custom degas separator, using the DS-1600 as their design basis.

Design Degas Separator Prototype

The ASR-II project engineers at Burns and McDonnell asked Mazzei to design a degas separator with a maximum inlet height of 16.4 feet that would process the two phase, 5 MGD flow and remove a maximum of a 1.4 % entrained gas volume (50 SCFM), at a maximum degas separator water inlet pressure of 1 psig. Pilot testing of the prototype degas separator would be witnessed by a Burns and McDonnell representative. Failure to meet project requirements would require additional modifications to the separator or, if additional modifications were not available, its removal from the project.

The challenge of designing the custom degas separator was significant. Processing the AOP two-phase effluent at a motive separator inlet pressure of 1 psig, required a modification of the separator's internal accelerator plate that would reduce its internal spin velocity below that required for vortex formation and gas bubble removal. Consequently, Mazzei took exception to the requirement, asking for the approval of a degas separator design with a 5 MGD motive inlet pressure of 1.5 psig. The alternative design criteria was

Table 1. Commercially Available 5 MGD GDT™ Degas Separators

GDT™ Separator (Model)	Design Flow (MGD)	Required Inlet Head (Feet @ 5 MGD)	Inlet Height (Feet)	Total Head (Feet)
DS-1200	2.9 - 5.0	20.8	15.1	35.9
DS-1400	3.5 – 6.5	11.5	16.6	28.1
DS-1600	4.6 – 9.2	5.8	17.8	23.6

accepted by the project engineers, releasing Mazzei to proceed with the fabrication of the degas separator prototype.

Performance Testing

Twelve weeks following approval of the prototype design, the degas separator was ready for performance testing. Surface finishing and weld passivation, however, were not completed in case test results showed a need to make further modifications to the separator.

Separator performance testing was conducted at the Fresno State University Water & Energy Technology (W.E.T.) Laboratory in Fresno, CA. To have sufficient head room for the degas relief valve assembly, the 4,400 lbs (1,996 kg), 19.5 ft (5.9 m) tall degas separator was installed into the facilities recirculation trough (Figure 3).

Additional equipment and instrumentation utilized included a 6,000 gpm centrifugal pump with a variable frequency drive (VFD) , a water venturi meter, air compressor, an air sparging spool with a perforated, gas inlet line for small bubble mixing of the 50 SCFM air flow into the pre-separator water line, pressure transmitters with visual pre and post separator site glass tubes, calibrated in inches, to confirm separator hydraulic working pressures, two anemometers to measure air flow at the compressor air inlet and the relief valves discharge port, and a downstream automated plug valve to set the degas separator's working water level (Figure 4).

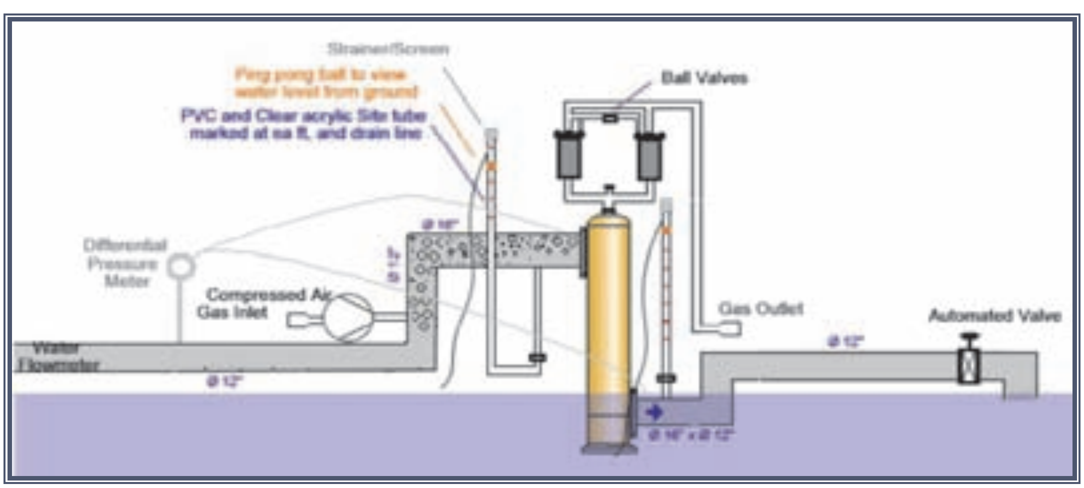
The initial test run of the degas separator was successful. Degas separator pressure loss at 5 MGD met the project design criteria and, visually, removed all entrained gas bubbles. To quantify gas removal, the pre-separator air flow was measured at the air inlet of the compressor, simultaneous with the measurement of air flow out of the degas relief valve, using anemometers calibrated to an SCFM readout. Gas removal averaged 97.4%, calculated as off-gas SCFM/gas inlet SCFM. Gas removal was based on the direct reading of air flow out of the degas separator and not corrected to account for the partial mass transfer of air into the water stream. Table 2 shows all of the test data collected from multiple test runs.

Figure 3. Seating degas separator into sump.

Conclusion

The final test run witnessed by Burns and McDonnell verified degas separator performance, resulting in final approval of Mazzei's submittal to supply ASR-II with six custom DS1600-LF GDT TM Degas Separators. he success of the custom degas separator is due, in large part, to the encouragement and support we received from Burns and McDonnell, as well as to the design skills of the engineers at the Claude-Laval Corporation, our partner in the development of the custom GDT TM Degas Separator. Mazzei's access to Fresno State's W.E.T. lab was also crucial to our success. The ability to verify design performance at plant operating conditions was a critical part of ensuring that the separators would perform to project specifications at the job site.

Figure 4. Degas separator process testing set-up



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6. Conversations with Debra E. Ary, Superintendent of Production and Pumping, City of Wichita, KS

7. Conversations with Tye McGown, ASR-II Project Engineer, Burns and McDonnell, Kansas City, MO

8. Conversation with Bill Nezgod, Municipal Sales Manager,

Table 2. DS-1600 LF-A Test Data

Test Run	Separator Water, Flow (GPM)	Compressor Air Inlet (SCFM)	Separator Inlet (PSIG)	Separator Outlet* (PSIG)	Separator Air Out (SCFM)	G/L (Ratio)	Gas Removal (%)
1	3,210	63.445	0.93	0	61.94	0.148	97.6
2	3,196	55.485	1.09	-0.433	55.985	0.130	100.9
3	3,184	46.71	1.62	-0.216	43.805	0.110	93.8
Average	**3,196.7**		**1.2**	**-0.2**			**97.4**
1	3,468	51.9	1.73	-0.216	50.9	0.112	98.1
2	3,462	62.05	1.73	-0.216	60.37	0.134	97.3
3	3,460	42.62	1.73	-0.216	41.42	0.092	97.2
Average	**3,463.3**		**1.7**	**-0.2**			**97.5**
1	3,807	42.86	1.515	-0.866	41.02	0.084	95.7
2	3,807	63.81	1.515	-0.866	61.81	0.125	96.9
3	3,812	56.77	1.515	-0.866	56.53	0.111	99.6
Average	**3,808.7**		**1.5**	**-0.9**			**97.4**
Total Average	**3,489.6**		**1.5**	**-0.4**			**97.4%**