Retrofit of Ozone Installations with Side Stream Injection and Degasification

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ABSTRACT

Ozone has been incorporated as part of water treatment processes used in numerous industries. The ozone contacting system is a critical process in overall treatment plant performance. Ozonation system performance in many potable and industrial applications can be compromised by changes in raw water quality or by poorly designed ozone contacting systems. Increased ozone demand can stretch system operation beyond the original design capabilities while low mass transfer efficiency will reduce system performance even under design demand conditions.

In many cases, the answer to non-performing or borderline system operation is improving the operation of the ozone contacting system rather than installing a larger ozone generator. Enhancing ozone mass transfer efficiency can effectively reduce ozone generator operational output requirements by up to 30% in many cases.

This paper will report on the retrofit of several ozone installations with the highly efficient GDT™ pressurized ozone injection and entrained gas removal process. Examples of ozone system performance relative to flow rate, side stream ratio, applied ozone dosage and ozone generator output including field performance data before and after retrofit will be evaluated.

San Diego Zoological Park

The task of maintaining a healthy fish population and a water clarity that provides a 30 - 40 foot visibility within the San Diego Zoo's Hippo exhibit was particularly challenging. Fecal matter excreted by the large aquatic mammals makes this aquarium a close cousin to a municipal wastewater system.

The life support system design for the 210,000 gallon fresh water exhibit includes system recirculation at 3,000 gpm through filtration and ozonation steps. Screening and filtration is utilized to remove filterable organic and inorganic suspended solids. Following

filtration, the injection of ozone provides additional BOD reduction (oxidation and microflocculation) and disinfection.

Within two months of start-up of the zoo's Hippo exhibit, water quality deteriorated. Cloudy water, low ORP levels and high bacterial counts suggested insufficient ozone feed rates (dosage) and poor removal of organic matter. Efforts to improve water quality with increased ozone feed rates and additional filter backwash proved futile. The ozone contactor effluent ORP level remained more than 200 mV below the 700-750 mV level desired for adequate disinfection with the 8 lbs./day oxygen fed ozone generator set at maximum output.

The original ozone contacting system was a two train design utilizing Mazzei 2081 injectors, with each injector discharging into a pressurized (30 psig) 250 gallon contact vessel for detention time and entrained gas removal. To provide entrained gas bubble removal, vessel internals included baffling which provided a directional change in water flow. Separated gas bubbles from this baffled tank were then expelled through a relief valve at the top of the contact vessel. *See Figure 1.*

The low gas to liquid mixing ratio at the injector (0.04) and high gas to liquid mixing pressure (30 psig) were within the parameters known to provide a high ozone mass transfer efficiency, consequently it was suggested that the ozone generator was not making its specified output.

Once generator output was verified, the zoo considered purchasing a second ozone generator to boost the applied ozone dosage. Prior to making another capital investment, the zoo made a last ditch effort to fine-tune the existing water treatment system, by calling in two well known aquarium consultants. Each consultant did a quick review of the exhibit design and each recommended some modification of the filter system and the retrofitting of the exhibit with a GDT™ ^{side} stream ozone contact system.

Watters Life Support was selected to implement system design changes[1]. The Watters consulting team examination of the original ozone contacting system revealed that the internal tank baffling caused hydraulic short circuiting, resulting in only a fractional use of the available vessel volume. It was estimated that only 10% of the hold up volume was utilized due to system short circuiting.

The consultant also discovered that the extended distance from the injector outlet to the contact vessel had a negative effect on ozone mass transfer. The 30 foot pipe run between the injector and the contact vessel caused the micro-bubbles leaving the injector to coalesce to large bubbles moving along the top of the pipe to the contact vessel. Upon entering the contact vessel, this "slug flow" quickly rose to the tank outlet, reducing contact time as well as the interfacial mixing required for high mass transfer. Additionally, the tank baffling design incorporated low velocity flow rates to encourage gas bubble removal by coalescing of small gas bubbles entering the vessel into large gas bubbles.

Based upon their final review and recommendations, a single GDT™ system[2] was installed, utilizing the existing Mazzei 2081 injectors, but replacing the dual 250 gallon pressurized contact tanks with a single 200 gallon GDT™ reaction vessel and GDT™ DS-300-WM degas separator. The close placement of the injectors in conjunction with the new reaction vessel replaced plug flow mixing with aggressive, small bubble (bubble froth)[3] mixing utilizing 85 % of the reaction vessel volume. *See Figure 2*

The increase in interfacial mixing and tank detention time made a significant difference in the ozone mass transfer efficiency, measured as ORP. The morning following the installation of the GDT equipment, the zoo's Life Support Manager, Joe Arlotto, reported a significant improvement in water clarity and a 200 mV jump in water ORP levels, indicating improved ozone mass transfer while operating at 7 lbs./day generator output[4].

Confident from the success of the Zoo's Hippo exhibit retrofit, the San Diego Zoo has decided to retrofit other boarder line performing exhibits with the GDT™ process. The next retrofit will be at the Zoo's Polar Bear exhibit. The Polar Bear retrofit will utilize the existing dual pumps, 1584 Mazzei injectors and contact tanks. The contact tanks will be modified with the existing tank internal baffling changed to insure more complete tank volume utilization.

Mazzei® Mass Transfer Multiplier™ nozzles will be installed in the tanks to insure aggressive, small bubble mixing, with a GDT ™ degas separator to provide final gas mixing and entrained gas bubble removal. The goal of the retrofit is to make sufficient improvement in ozone mass transfer, to allow for the needs of the Polar Bear exhibit while providing excess ozone generator capacity to treat a near by small aquatic exhibit.

Ocean Park and Pacific Water Companies

The Ocean Park and Pacific Water Companies have been providing potable water to communities in the State of Washington for the past 35 years. In 1990, the companies formed a partnership and today provide water for over 2,500 domestic service connections. For many years, the water systems operated without the addition of chlorine or other chemical additives. However, over the past 5 years, a growing water demand and increased regulatory pressure has required the companies to take steps to improve the quality of their water product.

In January 1998, Phil Leach, the Pacific Water Company's Operations Manager, contacted GDT Corporation to discuss air binding problems with their media filter which began after implementing ozone treatment to oxidize iron, manganese and sulfide ion (S^{2-}) from the water system. The well water was contacted ozone from a 25 g/h oxygen fed ozone generator using two (2) Mazzei injectors *(See Figure 3)*. Passive degassing using a PVC standpipe and air relief valve of the 100 gpm well flow from was not providing sufficient entrained gas removal resulting in filter gas binding and or water flow channeling.

Additionally, the water leaving the filter was super saturated with oxygen resulting in effervescing on pressure release with resulting “milky water” customer complaints.

GDT proposed system modification of the full flow ozone contacting system to a GDT™ side stream to improve gas bubble removal and to minimize full flow gas saturation[5]. In February 1998 a 30 gpm GDT™ side stream contactor was installed on a trial basis. *See Figure 4*

The utility found that utilizing a small GDT™ side stream provided mass transfer equal to full stream performance with more efficient gas bubble removal and reduced total dissolved oxygen levels in the main stream eliminating milky water complaints. The resulting elimination of filter bed air binding enhanced the removal efficiency of the oxidized iron and manganese and minimized filter backwash by extending filter runs. At the end of the trial period, the decision was made to keep the GDT equipment as a permanent part of the ozone treatment system.

Pacific Water's success with retrofitting their filter with the GDT ^{TM} process has since led to an additional installation at an Ocean Park well site. In April 2000, Pete Christoson[6], CEO for both Pacific and Ocean Park Water Companies, ordered a second GDT^{TM} ozone contacting system for another 100 gpm well site that contained excessive concentrations of iron and manganese. Oxygen fed ozone is aspirated into a 25 gpm side stream contact train. Dissolved ozone levels sufficient for full flow oxidation of iron and manganese are achieved before mixing with the 100 gpm well water flow. Following ozonation, the full flow enters a 3.5 minute detention tank to allow precipitates to grow to filterable size floc. The water then enters multimedia filtration for particulate removal to produce the desired water quality.

Recent water analysis indicates that the 25 % GDT ozone side stream provides sufficient full flow oxidation to remove over 98 % of the raw water iron and manganese (see Table) without air binding of the filter bed. The additional benefit achieved by utilizing a small GDT side stream system, was producing a finished water product with a normal dissolved oxygen levels.

The new GDT^{TM} side stream offered the Water Company a considerable improvement over the GDT equipment installed at the Pacific Water well site in 1998. The GDT ^{TM} side stream for small municipal systems utilized the new GDT wall mount DS-100WM degas separator and wall mountable reaction vessel in conjunction with a pump and a Mazzei 978 injector. With the exception of the pump, no floor space was required to install the GDT ozone contact train.

The Ocean Park and Pacific Water companies are very pleased with the performance of the GDT process over the past two years and the latest successful use of the new wall mount GDT^{TM} side stream. Pete Christoson, the CEO of both companies, has planned future ground water installations using the new GDT^{TM} wall mount ozone contact system.

Lowry Park Zoo

The Lowry Park Zoo is located just off the I-275 freeway in North Tampa, Florida. In addition to providing exhibits and activities for the enjoyment of the local Tampa community, the zoo also rehabilitates sick or injured Manatees that are rescued from Florida waterways. The number of animals within the zoo's exhibit at any given time varies from 2 to more than a dozen[7].

GDT Corporations first involvement with the Zoo began in the Fall of 1997 when Lowry Park's Director of Animal Programs inquired about the GDT side stream contactors utilized on Busch Garden's 4,000 gpm Hippo Exhibit. The Hippo exhibit contained many brightly colored tropical fish, a family of hippos and utilized ozone as its only mode of disinfection. Lowry's Director was impressed by the exceptional water clarity (30+ feet of visibility) of the Hippo Exhibit as well as the small footprint of the GDT side stream (15 % of total filtration flow).

Lowery Park's Manatee exhibit also utilized ozone as its primary disinfectant. However, the exhibit's water clarity was poor, the ozone system could not achieve a high enough ORP for disinfection (System ORP ranged from 100 - 150 mV.) and the exhibit had experienced excessive micro-bubbles in the viewing tank. In addition, there had been several fish kills related to gas bubble carry over and the Parks frequent need to supplement ozone disinfection with chlorine injection.

The life support system for the 250,000 gallon exhibit consisted of 6 pressure sand filters operating at a total 6,000 gpm, dual 8 lbs./day air fed (1-1/2% by weight) ozone generators and a 20 foot x 14 foot x 20 foot high Fine Bubble Diffusion (FBD) contact basin. Approximately 55-65 % of the filtration loop flowed through the FBD basin and then into a deaeration tower to strip out dissolved ozone and excess dissolved gases. The ozonated-deaerated stream would then blend with raw filter water and gravity flow to the exhibit.

Changes in filter loading effected total system flow rates, with increases and decreases in the FBD basin flow rate often resulting in excessive micro-bubble carryover to the exhibit. Consequently, the FBD basin by pass valve required constant fine-tuning to achieve the ideal deaeration tower flow velocity that eliminated bubble carry over.

The deaeration tower operated as an uncovered stripping basin which, resulted in excessive ozone off gas during periods of bubble carryover. The effect of the ozone off gas was evident by the pungent smell of ground level ozone and the browning of nearby foliage.

High organic loading of the aquarium required excessive back washing of the exhibit's filtration system, resulting in an average make up rate of 45,000 gallons per day. Make

up water was provided by four on site wells, which contain hydrogen sulfide concentrations ranging from 0.78 to 2.08 mg/L.

All previous reviews of the system were done informally, by consultants, peer groups and ozone manufacturers. All had concluded that the sulfide in the make up water was quenching the ozone in the FBD basin, with one report suggesting that increasing the ozone feed rate to 50 ppd would handle the high ozone demand of the make up water.

A detailed review of the exhibit's operation indicated that insufficient ozone was not the primary problem. The almost 6:1 dilution of the make up water by the 250,000 gallon water system and the batch nature of the life support system (Exhibit had a 42 minute system turn over.) indicated that ozone demand, even at peak sulfide concentrations of 2.08 mg/L, would range no higher than 0.07 mg/L or about 96 grams per hour for the 6,000 gpm filtration loop.

Further investigation indicated that the primary problem was poor performance of the diffusion stones due to leaking gaskets and both internal and external deposits. The large, unevenly distribute gas bubbles provided poor mass transfer and excessive ozone off gas. The sensitive hydraulics of the FBD basin, which required a constant adjustment of the by pass valve to prevent bubble carry over, was a secondary problem relating to the system's over all design.

It was recommended that the Zoo either hire a life support consultant or else team up with a larger zoological peer to help them do one last, comprehensive review of the entire life support operation. A secondary recommendation was for the zoo to consider utilizing an oxygen fed ozone to produce a more concentrated ozone gas stream. The use of oxygen fed ozone would then facilitate the use of a small GDT side stream which would provide high ozone mass transfer and reliable gas bubble removal.

Following several months of discussion and review, the zoo decided to upgrade the ozone system. Since the existing ozone generators were no longer manufactured, the Park decided to install new oxygen fed ozone generators. Two (2) Ozonia CFS-2 generators each with a capacity of 8 lbs./day at an ozone gas concentration of 6 % by weight were selected. The use of a concentrated ozone gas stream allowed the Zoo to change ozone contacting from the 20' x 14' x 20' tall FDB basin to a much smaller 8’ x 4' x 5' tall GDT side stream contact system.

Changes in system flow rates due to filter loading have had a negligible effect on the performance of the GDT side stream. The new ozone life support system in conjunction with improvements in filter backwash, provides water clarity that is exceptional, with a greater than 30 foot of visibility and produces exhibit ORP levels ranging in the low 300's with the ozone generators set at only 50 % of their total output. Bubble carry over is non-existent, supplement feed of chlorine has been discontinued and the system now boasts a variety of fish as part of the Manatee habitat.

Additional retrofit plans are in the works to further reduce the Manatee exhibit's ozone demand, so that the Park may use the existing CFS-2 generators to also treat another near by exhibit. The planned retrofits include the installation of bio filters down stream from the GDT contact system and the air stripping of sulfide from the Park's 35 foot tall ground water storage tank, utilizing the patented Mazzei Airjection™ method for deep tank aeration.

Summary

The application of sound science in the mass transfer of ozone gas into solution with the efficient removal of gas bubbles from solution, is an integral part of the GDT process. Good interfacial mixing between the gas and liquid phases, through aggressive, small bubble mixing, and improved utilization of reaction tank volume will achieve optimum ozone mass transfer for any given applied ozone dosage. Rapid, efficient removal of gas bubbles with the GDT side stream insures against down stream filter problems and excessive high dissolved oxygen levels common to full flow contacting methods.

Industrial and municipal ozone systems can be retrofitted with the GDT™ process to improve the performance of ozone systems, which may be compromised by poor design, deterioration of equipment or increased ozone demand.

References

1. Personal communication with John Watters. CEO, Watters Life Support, April- June, 1999
2. J.R. Jackson, P.K. Overbeck, "Ozone Pipeline Gasification-Degasification Treatment (GDT™) Performance in Potable Water Treatment Plants", IOA PAG annual Conference Proceedings, 1997 Lake Tahoe, California
3. K. L. Rakness, L. D. DeMers: Process Applications, Inc., E. Sedeno: Southern California Edison, K. Ozekin: AWWARF, Draft: "*Results of the Ozone Facility Evaluation at the Mesa Consolidated Water District*", *Costa Mesa*, California Funding Agencies: Ozone Energy Efficiency Project-Phase II AWWARF Project Number 284-95
4. Personal communication with Joe Arlotto, Life Support Manager, San Diego Zoo, August 1999 & July 1, 2000
5. Personal communication with Pete Christoson, CEO, Ocean Park and Pacific Water Companies, June, 2000
6. J.R. Jackson, P.K. Overbeck, J.M. Overby, "Dissolved Oxygen Control by Pressurized Side Stream Ozone Contacting and Degassing" IOA World Congress Proceedings, 1999 Dearborn, Michigan
7. Personal communication with Steve Threvenin, Director of Maintenance, Lowry Park Zoo, April 2000

SAN DIEGO ZOO HIPPO EXHIBIT
Original Ozone Contacting

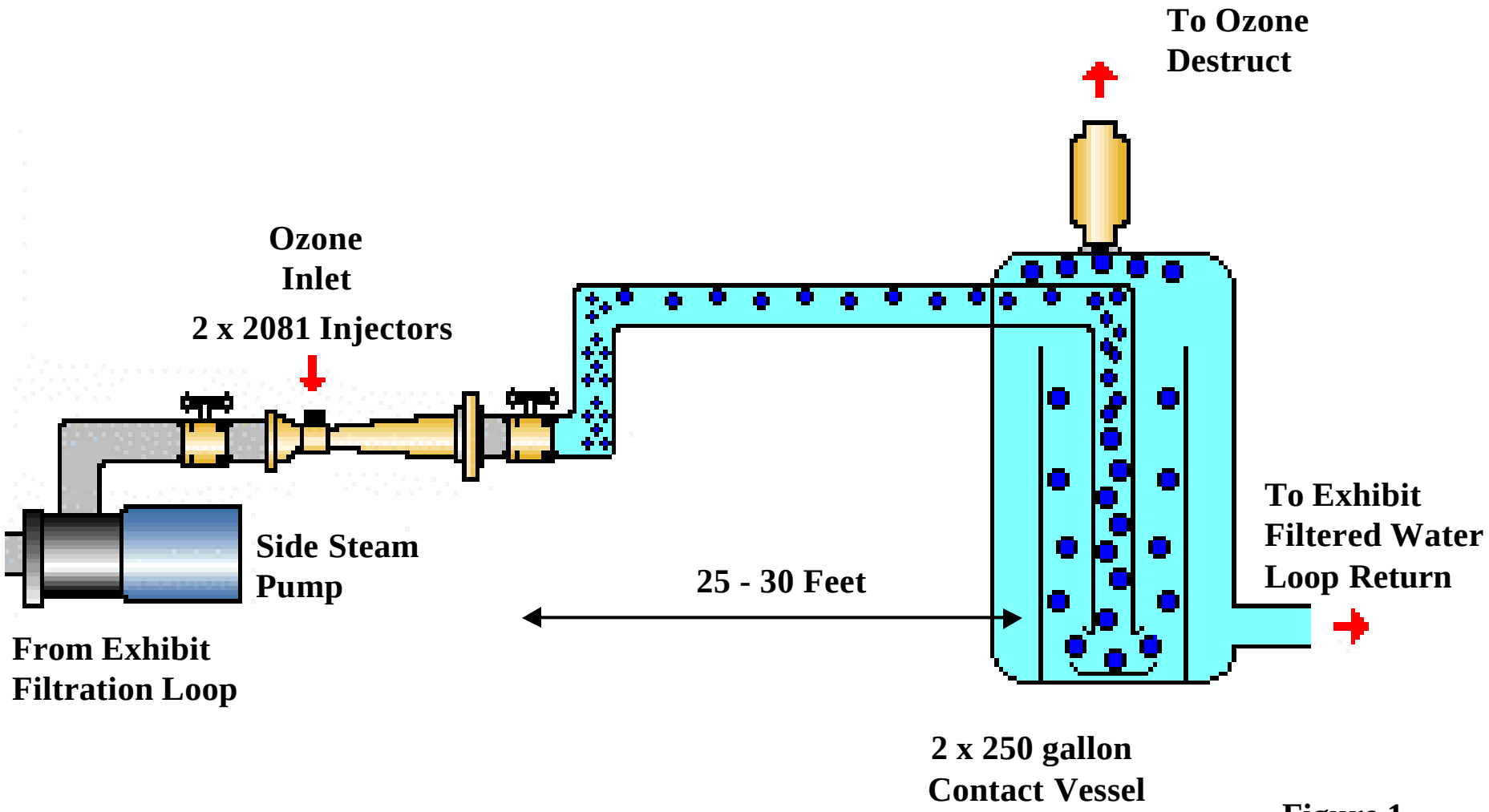

Figure 1

SAN DIEGO ZOO HIPPO EXHIBIT
GDT Ozone Contacting

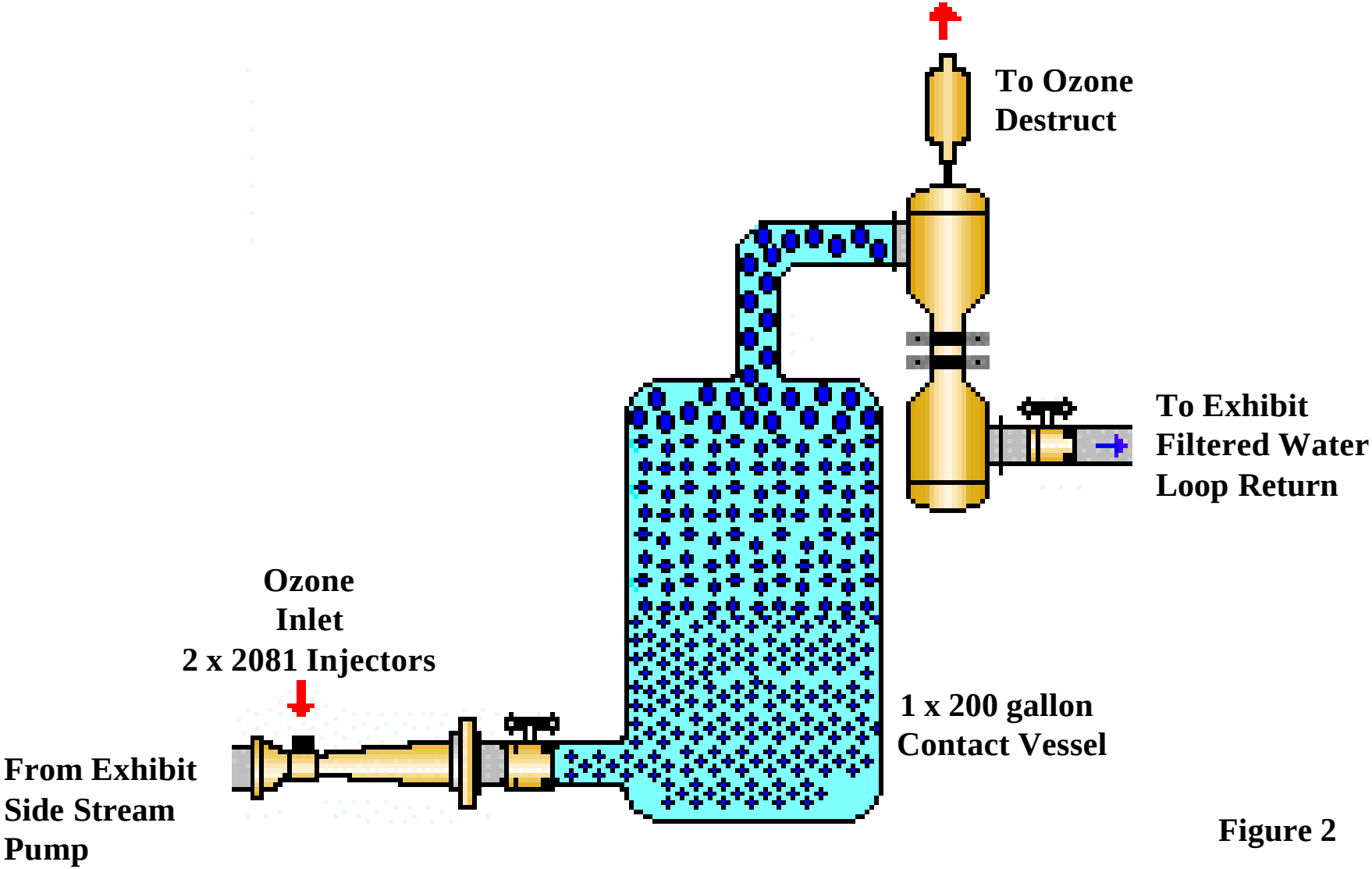

Figure 2

Ocean Park
Original Side Stream Contacting

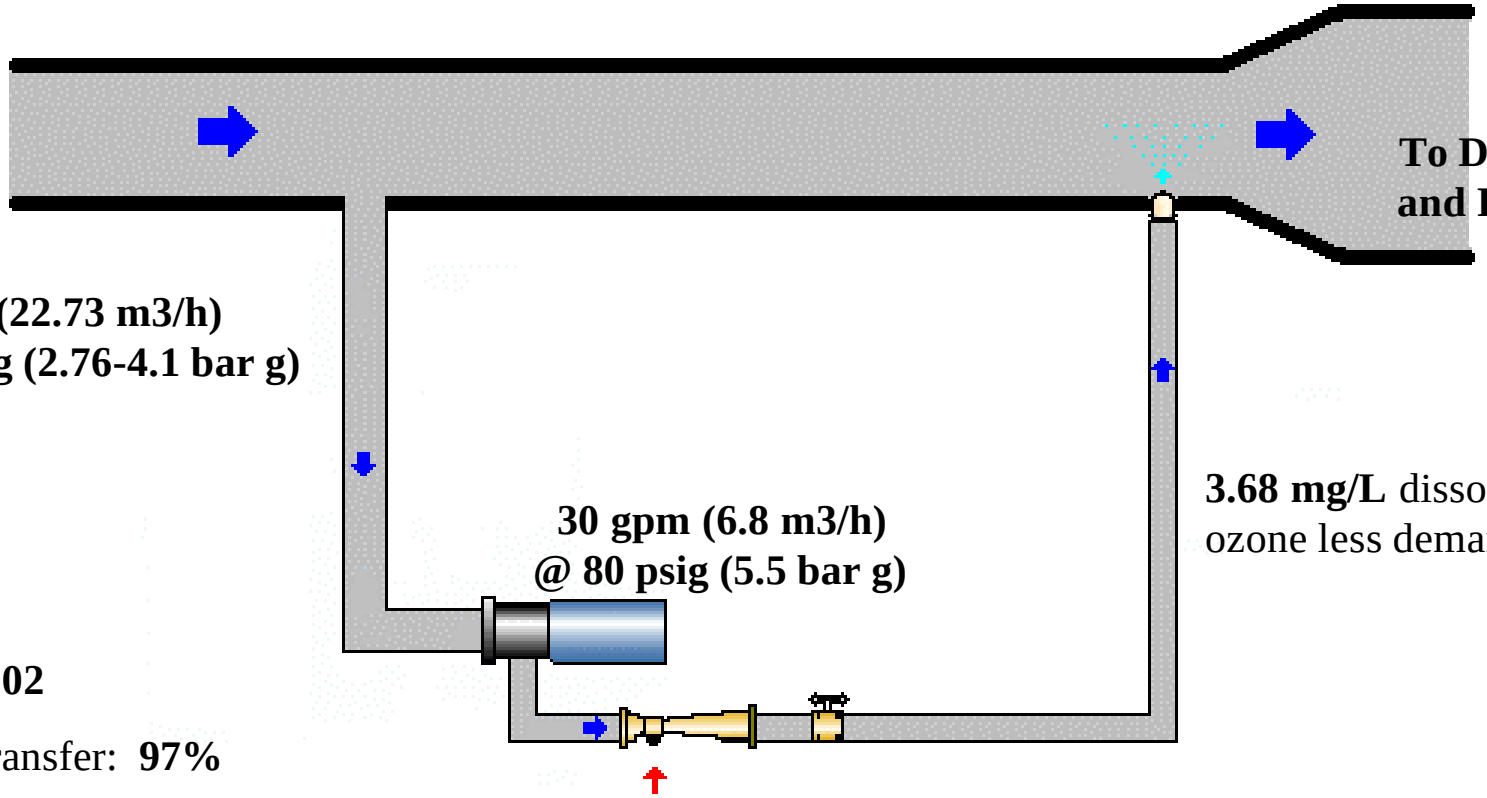

Figure 3

Ocean Park
GDT Side Stream Contacting

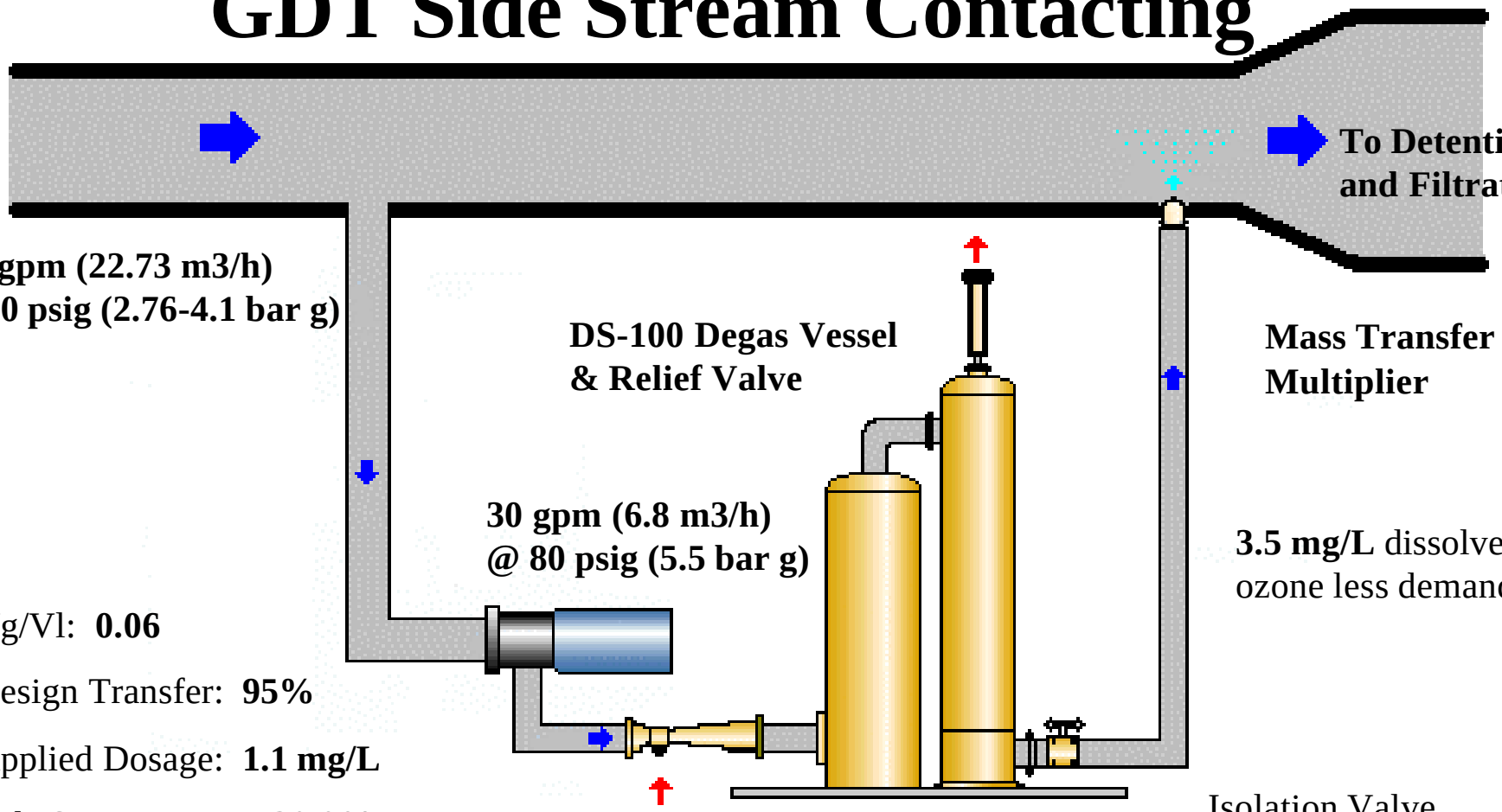

Figure 4