Enhanced Water Quality

And Disinfection

Through Ozone Gas Contacting

Jim Jackson

Mazzei Injector Company LLC.

TOPICS

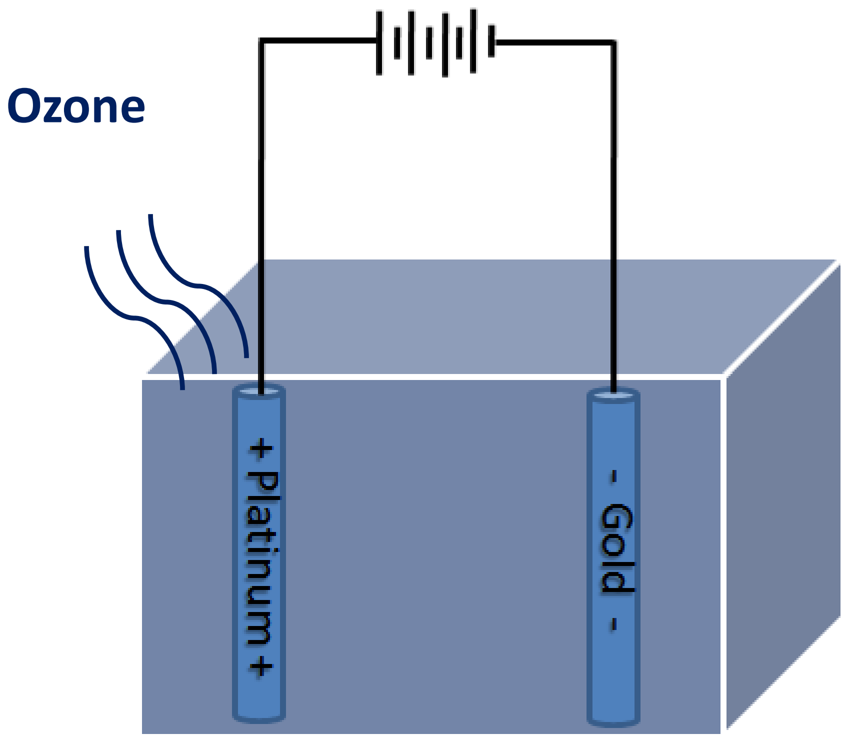
- **Ozone Basics**
  - Discovery, Basic Chemistry, Disinfection, Oxidation, Commercial Generation
- **Ozone Contacting: Dissolving Ozone Into Water**
  - Fine Bubble Diffusion Contact Basins
  - Sidestream Venturi Gas Injection
  - Secondary Gas Mixing Devices: Pipeline Flash Reactor & Basin Nozzle Manifolds
- **Case Histories:**
  - OUC SW WTP: Retrofit of 45 MGD O3 diffusion basins with SVI and Pipeline Flash Reactor for H2S oxidation
  - SW WWTP: Retrofit of 100 MGD wastewater ozone contact basin with SVI Basin Nozzle Manifolds

OZONE ?

FATHER OF OZONE

Christian Friedrich Schönbein
1799 - 1868

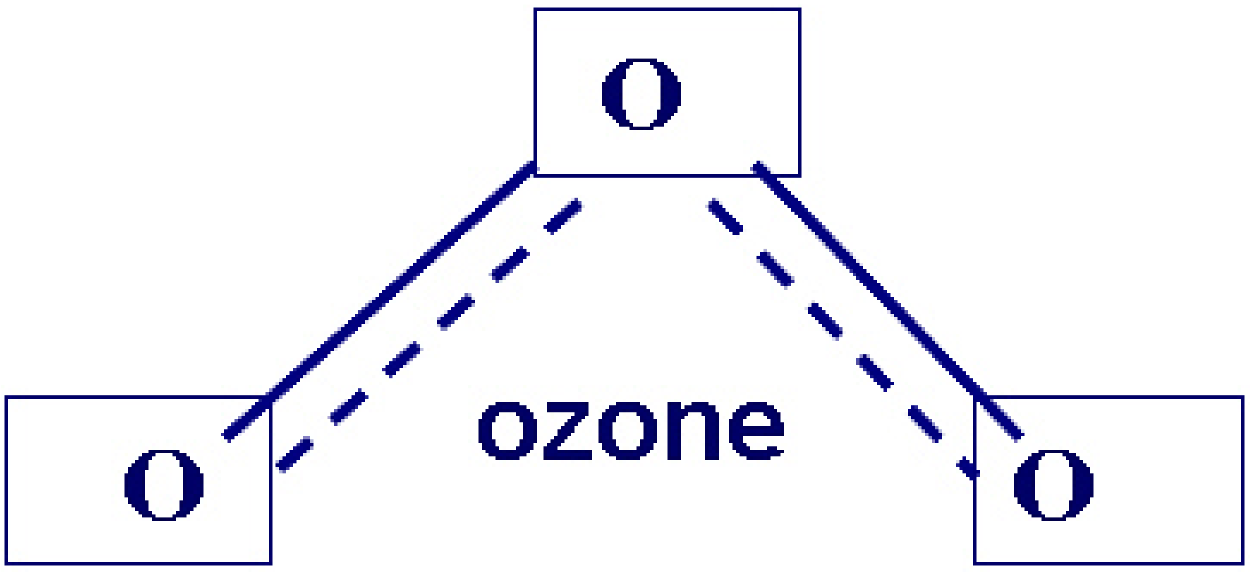
OZONE DISCOVERY
ELECTROLYSIS OF WATER
(March 13, 1839)



Electrode used non-oxidizable platinum and gold probes. Oxygen collected at the positive, platinum probe and gave off a smell.

BASIC CHEMISTRY

Ozone Generation



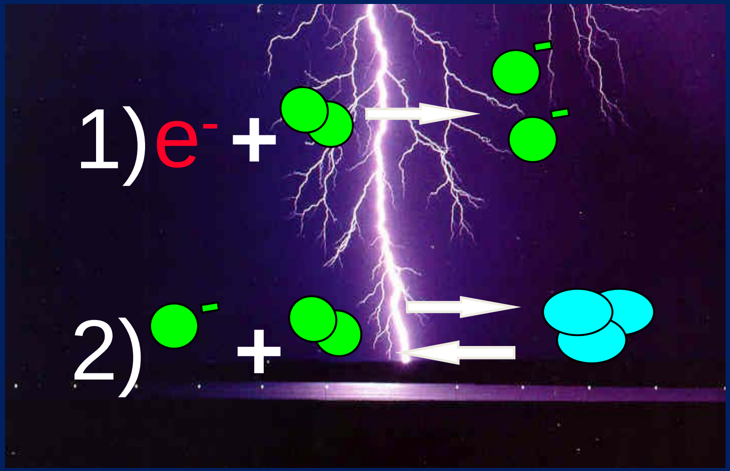
$$3\,O_2 + e^- \rightarrow 2\,O_3$$

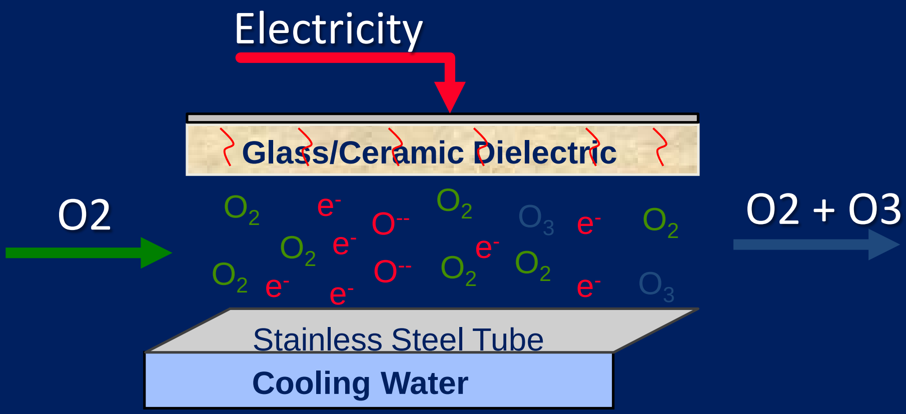
OXYGEN ELECTRIC SPARK OZONE

BASIC CHEMISTRY

Ozone Generation

- Ozone gas is formed from oxygen gas *via* an electrical discharge
- Ozone generators create "lightning strikes" within a narrow discharge gap
  - Gas must be dry
  - Gas must be particle free
  - Gas must be cooled





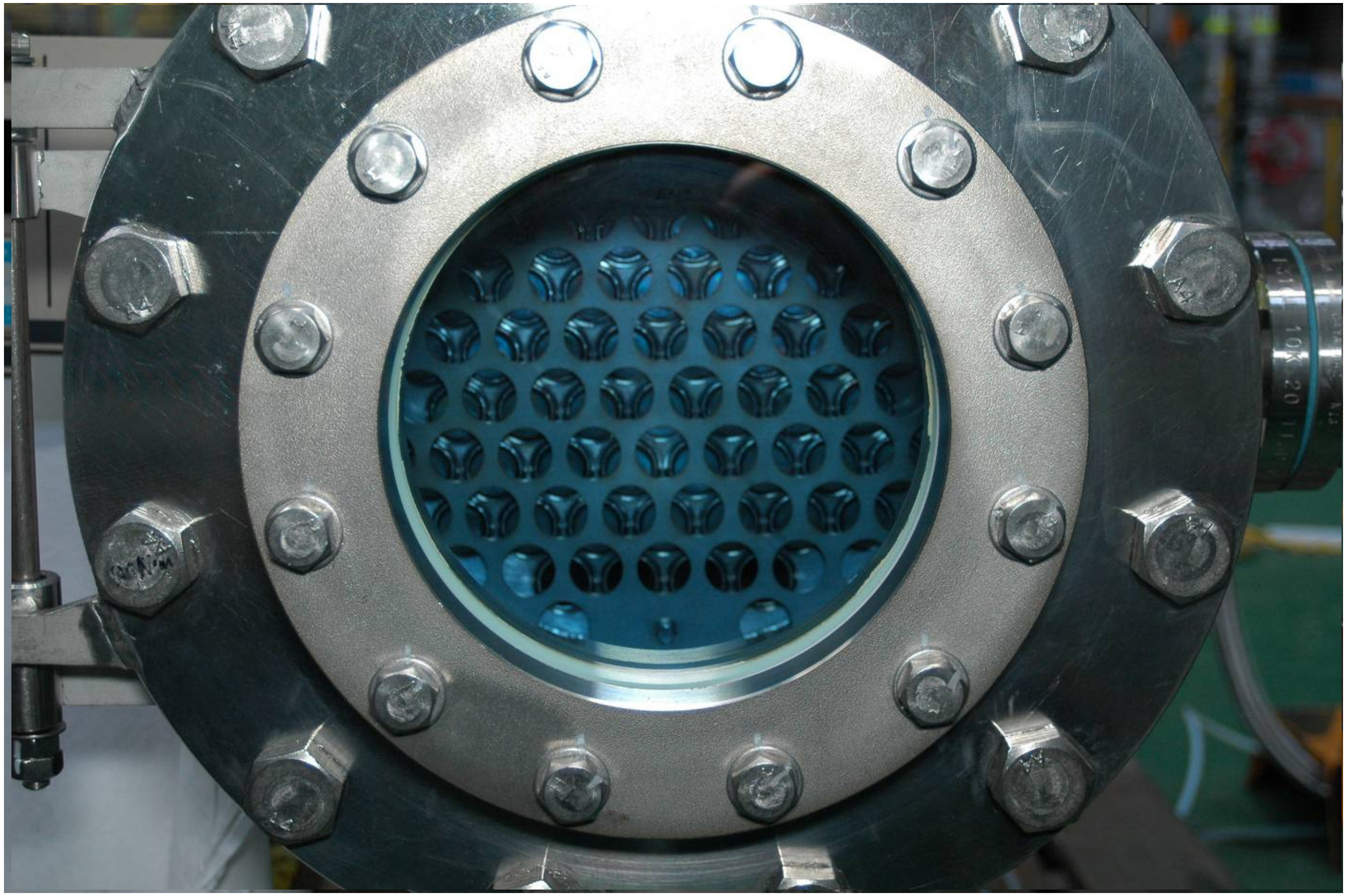
BASIC CHEMISTRY

Relative Strength of Ozone

OXIDIZING AGENT	EOP (VOLT)	EOP VS CL2
Fluorine	3.06	2.25
Oxygen (atomic)	2.42	1.78
Ozone	2.08	1.52
Hydrogen Peroxide	1.78	1.30
Hypochlorite	1.49	1.10
Chlorine	1.36	1.00
Chlorine Dioxide	1.27	0.93
Oxygen (molecular)	1.23	0.90

BASIC CHEMISTRY

-Ozone Is A Pale Blue Gas-



Ozone Concentration : 23 w/w%

BASIC CHEMISTRY

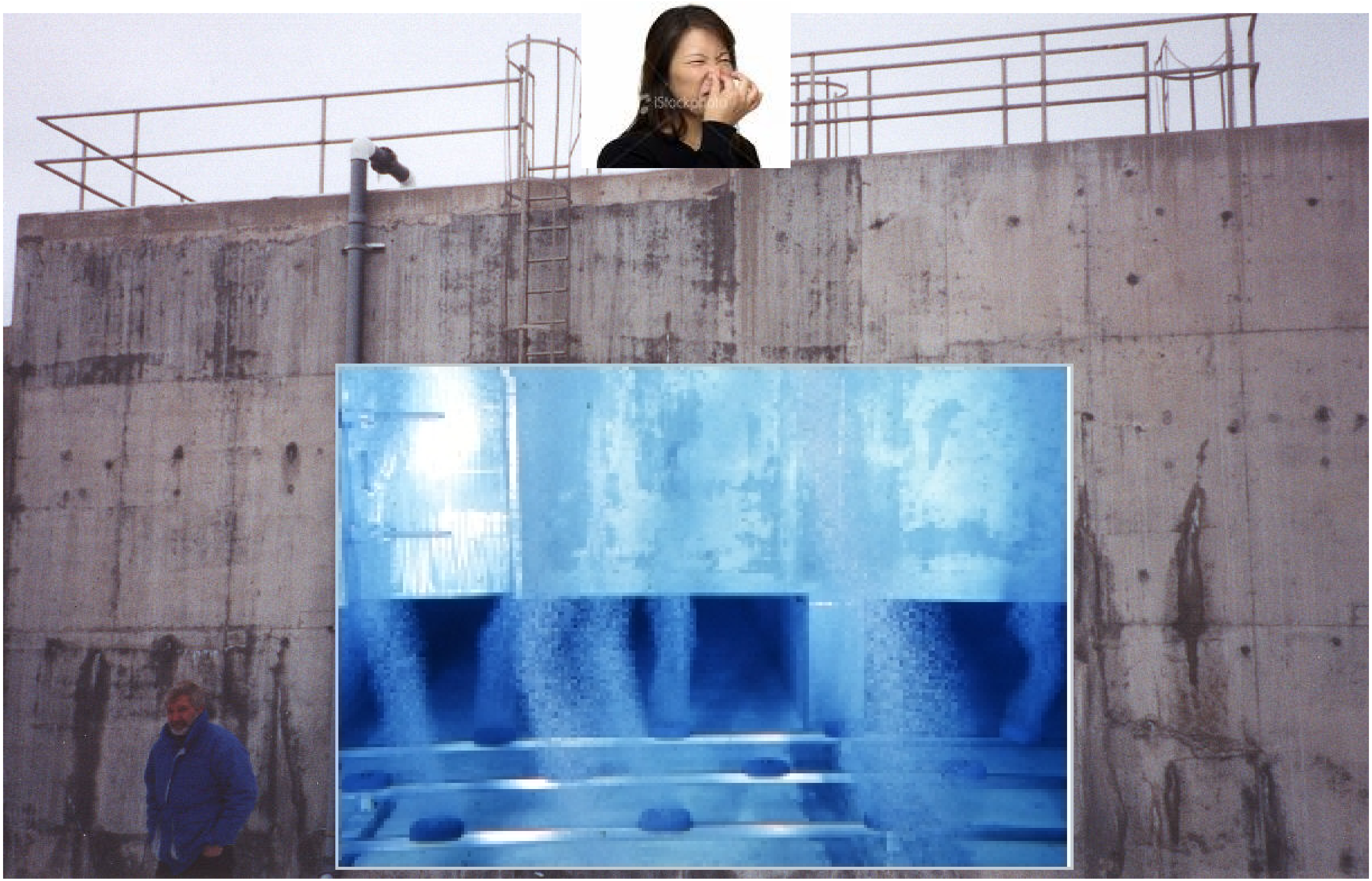
- Ozone does not combined with organics like chlorine.
  - All measured dissolved O3 is “free” O3

- Dissolved O3 is volatile and constantly leaves water as O3 gas.

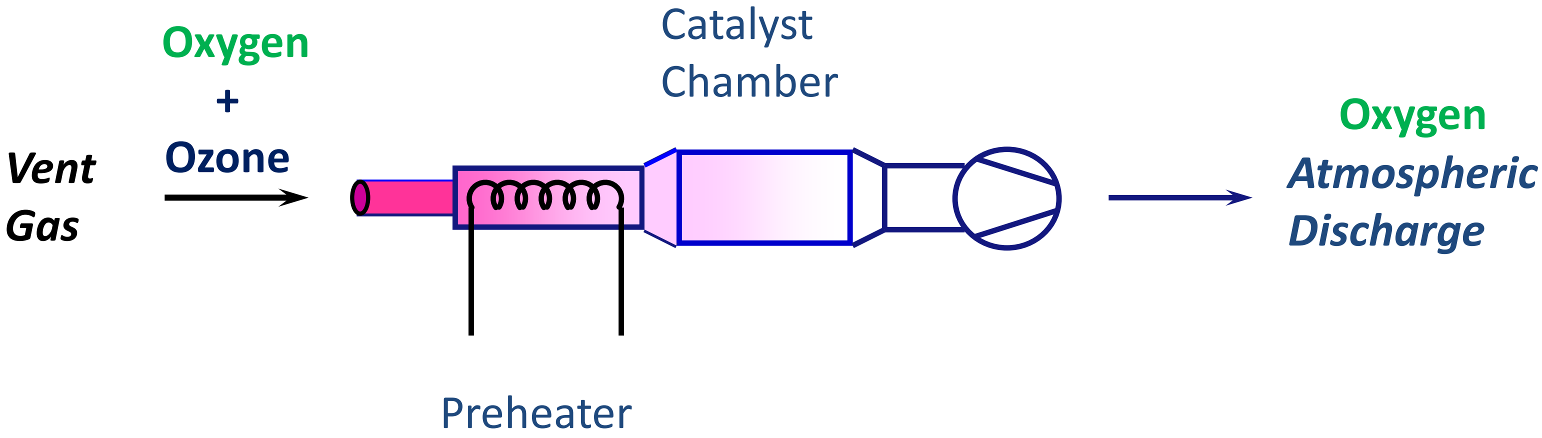
OZONE SAFETY

ISSUES

OZONE OFF-GAS



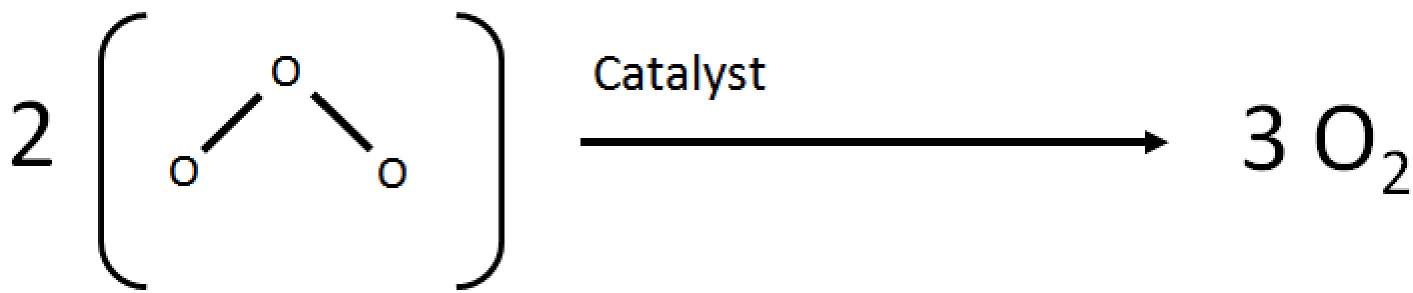
OZONE DESTRUCT + BLOWER



CATALYTIC DESTRUCTION OF OZONE

OZONE Destruction Efficiency is:

A. Consistent
B. Predictable



EFFECTS OF OZONE EXPOSURE

Condition	Ozone Concentration
Detectable odor	0.01 to 0.04 ppm_v
TLV-TWA 8-hr limit	0.10 ppm_v
Headache, shortness of breath	>0.10 ppm_v
TLV-STEL 15-min limit	**0.30 ppm_v**
Chest pain, dry cough, lung irritation, severe fatigue	0.6 - 1.0 ppm_v (1 - 2 hrs)
Immediately dangerous to life & health	10.0 ppm_v
Expected to be fatal	50 ppm_v (30 min)

Data from "Ozone Manual of Standard Practice", Workers Compensation Board of British Columbia, 1992

AMBIENT OZONE MONITORS

- Sound, visual, and computer alarms
- Sample from near floor level since ozone is heavier than air

Ambient Ozone

UV OZONE MONITOR IS THE GOLD STANDARD

- Measures based on the decay of ozone gas with UV.
- Does not alarm when contacted with chemical fumes and gases.

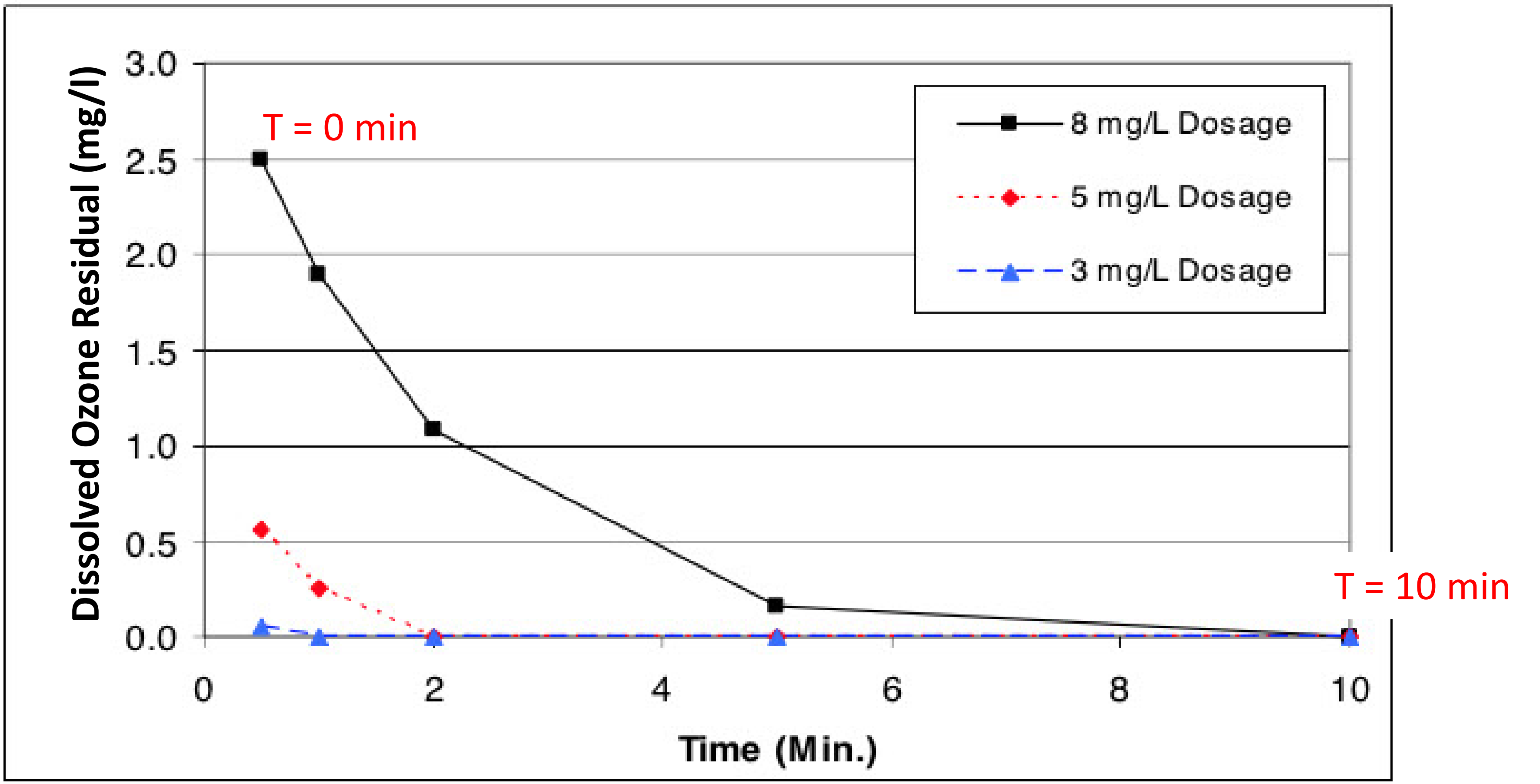
BASIC CHEMISTRY

- Ozone does not combined with organics like chlorine.
  - All measured dissolved O3 is “free” O3

- Dissolved O3 is volatile and constantly leaves water as O3 gas.

- Dissolved O3 concentrations change over time. Ozone constantly decays to secondary oxidants and oxygen.

OZONE DECAY CURVES



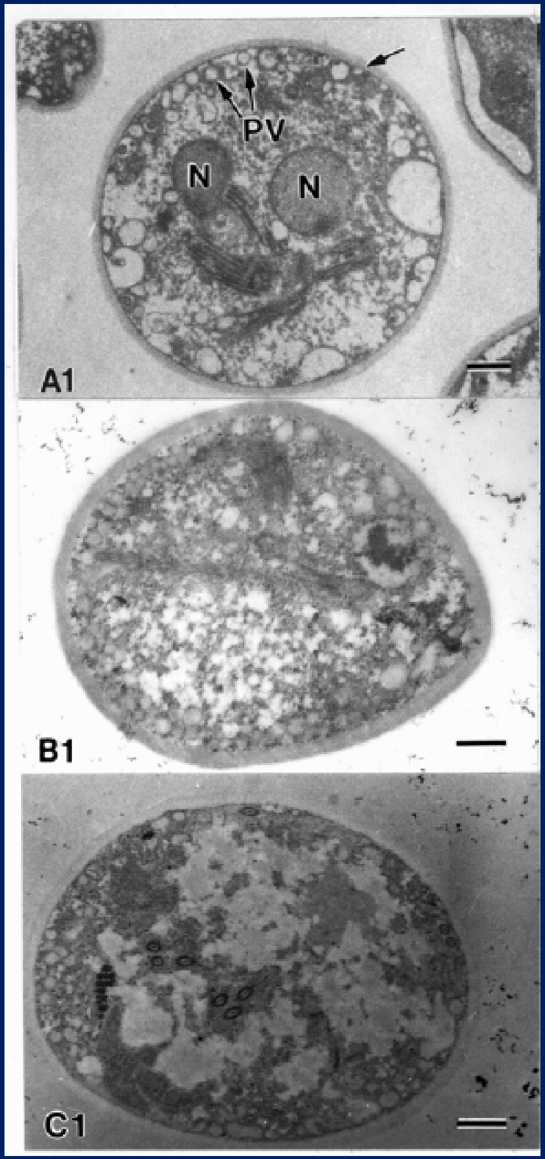
W H Y

O Z O N E ?

A 1993 WATERBOURNE DISEASE OUTBREAK

- Gastro Intestinal Illness: > 400,000 Milwaukee, WI Residents
- Mortality: 104 deaths, primarily the elderly and immunocompromised
- Financial Impact: $ 96 million in health care cost & productivity loss
- Pathogen: 4 – 5 um sized, chlorine resistant, Cryptosporidium parvum oocysts.
- C. parvum can be inactivated with exposure to small concentrations of ozone over a short period of time.

Giardia Cyst-Effects of O3 Attack



Control
pH 6, 25 C

Active
Pathogen
Will infect host

Moderate
Exposure:
0.5 mg/l
2 min

Inactive
Pathogen
Will not infect host

High:
Exposure:
.5 mg/l,
5 min

DISINFECTION JARGON

Pathogen Inactivation — Pathogen Can No Longer Infect A Host.

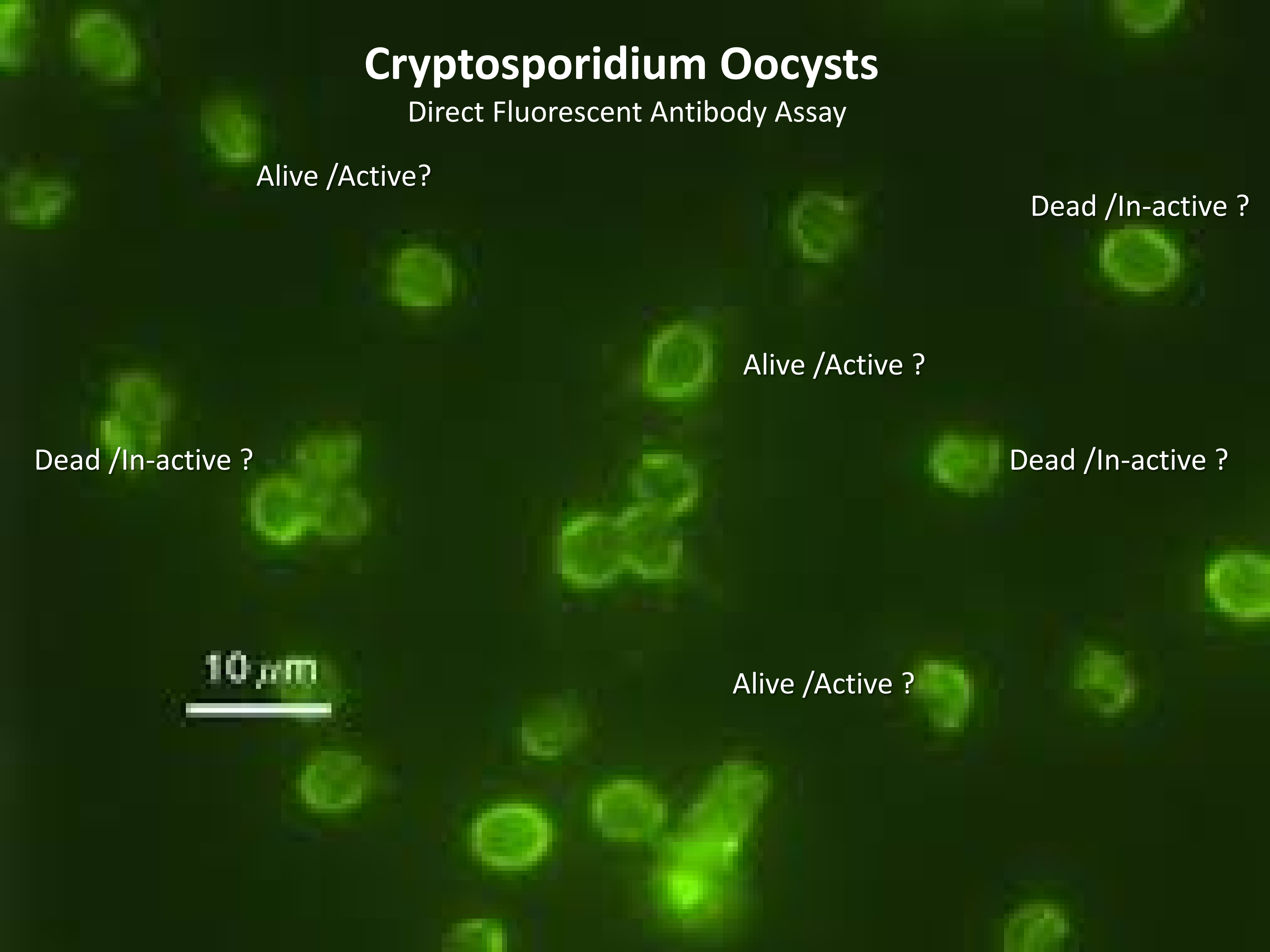
Log Removal/Log Inactivation — Number Of Removed/Inactivated Cells

$$\text{Log Removal} = \text{Log}\left[\frac{\text{Number of Organism In Raw Water}}{\text{Number of Organisms In Effluent}}\right]$$

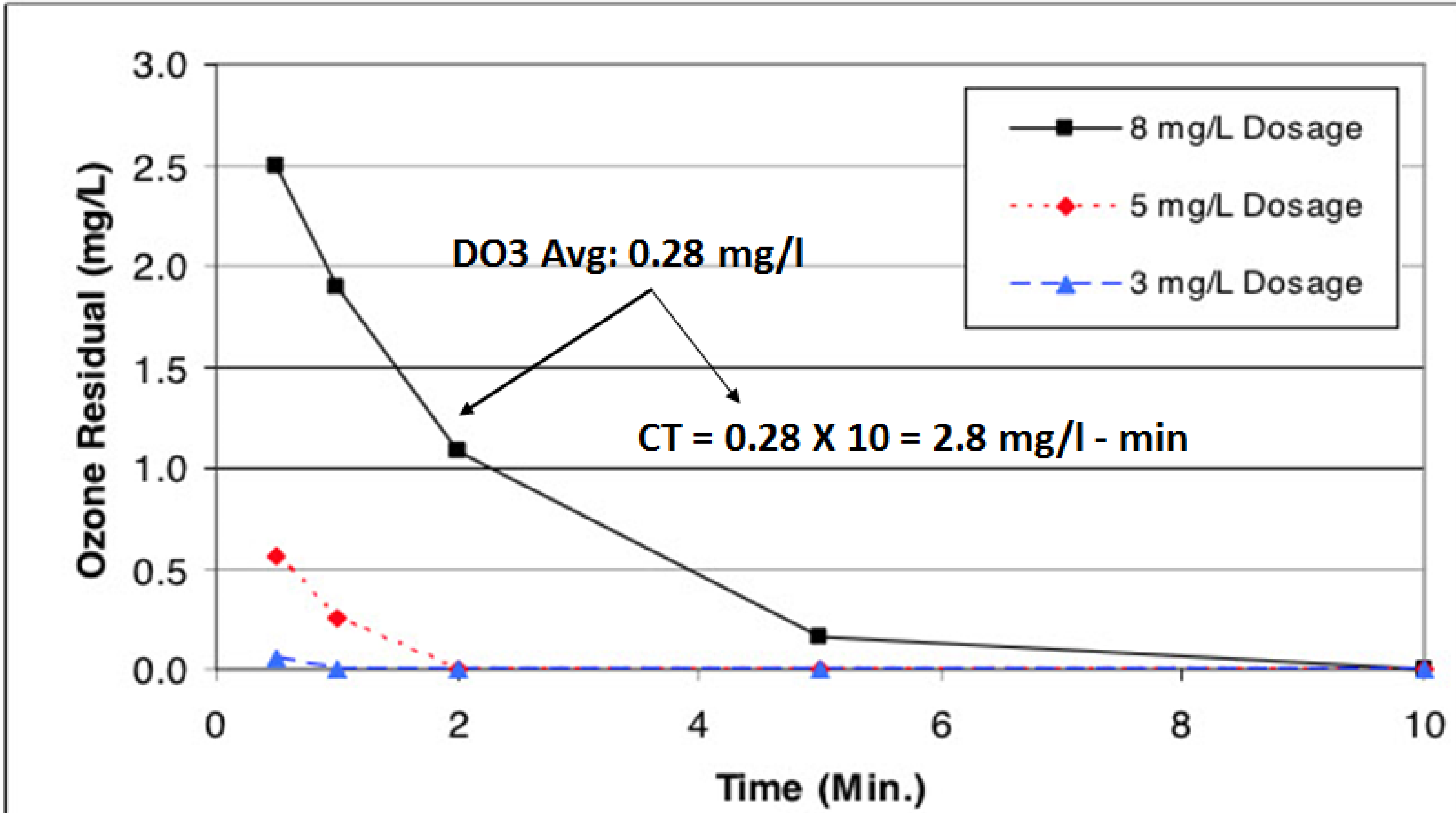
Log Removal/Inactivation	Percent Removal/ Inactivation
1	99 %
2	99.9 %
3	99.99 %

Cryptosporidium Oocysts

Direct Fluorescent Antibody Assay



DISINFECTION JARGON



DISINFECTION JARGON

Jargon Relationship

CT Values for Cryptosporidium Inactivation/Removal (40 CFR 141.730 Abridged)

LOG REMOVAL	INACTIVATION %	WATER TEMPERATURE, C°					
		5	7	10	15	20	25
1	90	16	13	9.9	6.2	3.8	2.5
2	99	32	26	20	12	7.8	4.9
3	99.9	47	39	30	19	12	7.4

Coagulation – Filtration (Cell Removal) + O3 Contact Time (Cell Inactivation) = CT Value

O Z O N E

O X I D A T I O N

OXIDATION APPLICATIONS

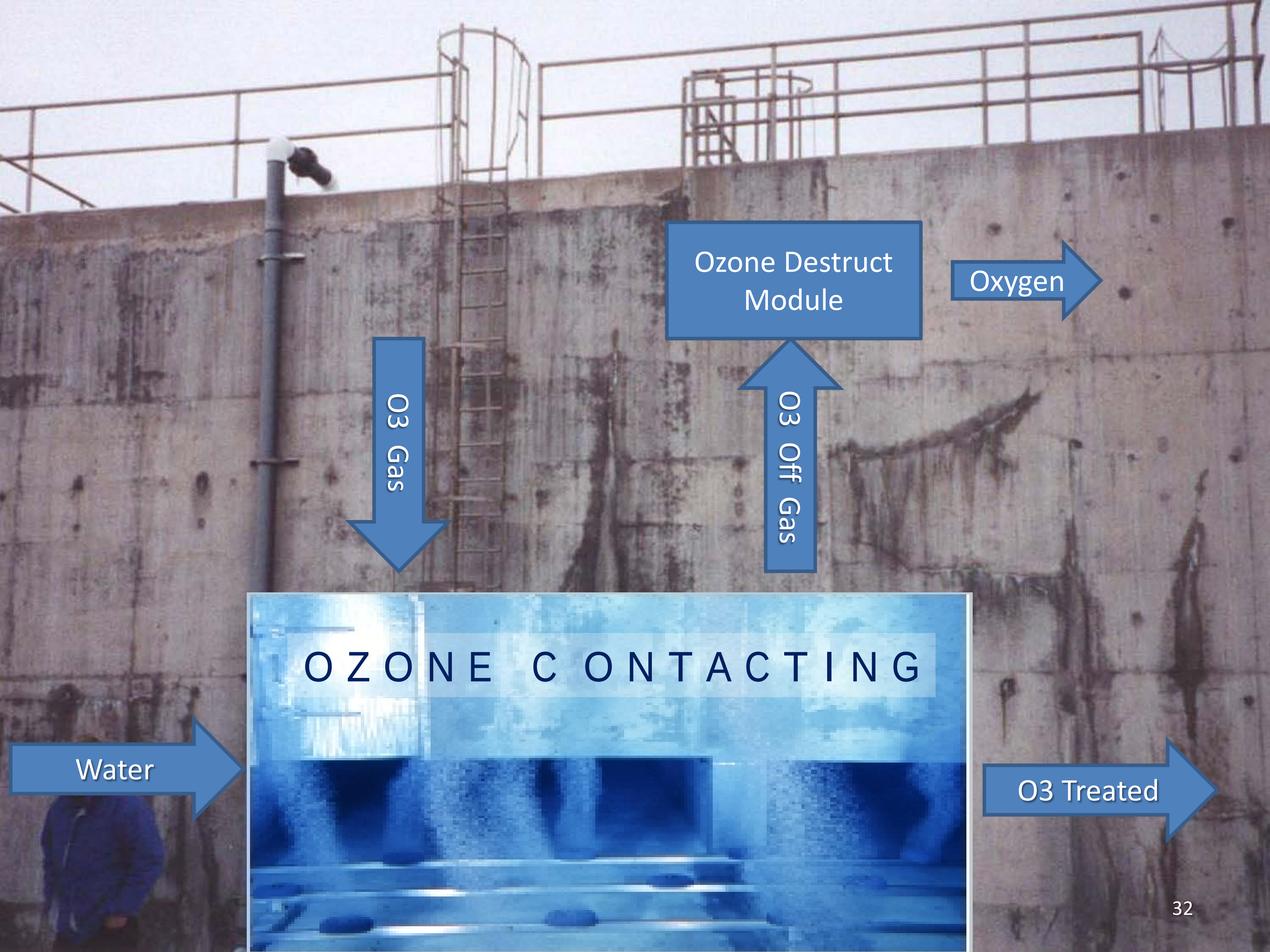
- Taste & Odor
  - Geosmin & MIB
  - H2S
- Metals
  - Iron and Manganese
- Toxins
  - Microcystins & Anatoxins (Blue-Green Algae)
- Micro-flocculation
  - Raw water pin-floc development with low dose ozone

MUNICIPAL OZONE SYSTEMS

OXYGEN SOURCE

OZONE GENERATION

(400 PPD O3 Generator)


Ozone Destruct Module
Oxygen
O3 Gas
O3 Off Gas
OZONE CONTACTING
Water
O3 Treated

> 90% of US municipal ozone installations use FBD contact basins.

Southwest WWTP
-Ozone Gas Injectors-

N. AMERICAN O3 CONTACT BASINS
Why Retrofit With Gas Injection?

Improved O3 Transfer Efficiency ?	No. Well designed FBD is efficient !
	Yes. Poorly maintained FBD is inefficient!
Confined Space Safety Concerns ?	Maybe.


300 done !
256 to do !!

N. AMERICAN O3 CONTACT BASINS
Why Retrofit With Gas Injection?

Improved O3 Transfer Efficiency ?	No. Well designed FBD is efficient ! Yes. Poorly maintained FBD is inefficient!
Confined Space Safety Concerns ?	Maybe.
Retrofit To Reduce Maintenance ?	Yes !

Checking Diffuser Gas Distribution

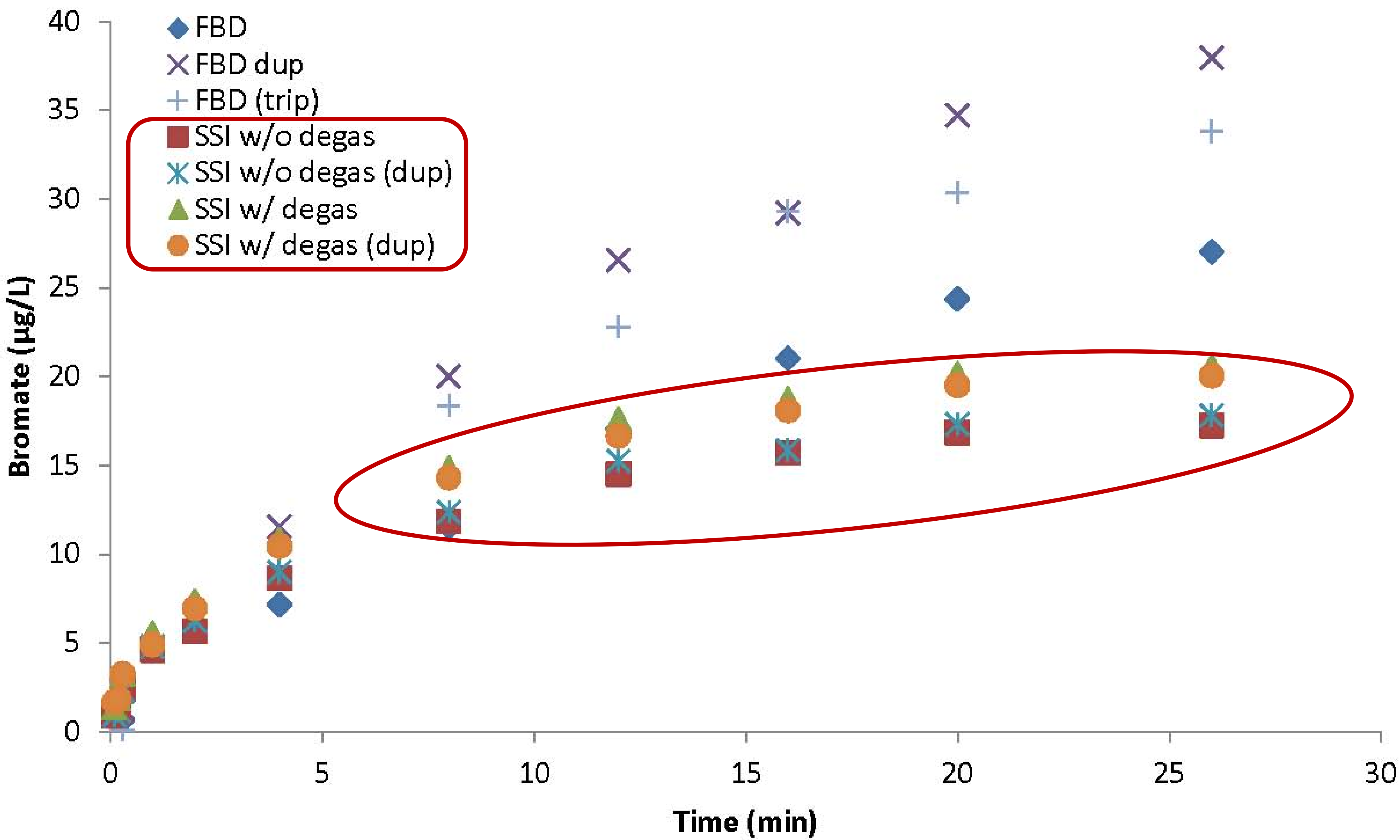
REVENUE LOSS DECREASES STAFFING

Injection Retrofit Replaces Man Hours With Kilowatt Hours

N. AMERICAN O3 CONTACT BASINS

Why Retrofit With Gas Injection?

Improved O3 Transfer Efficiency ?	No. Well designed FBD is efficient ! Yes. Poorly maintained FBD is inefficient!
Confined Space Safety Concerns ?	Maybe.
Retrofit To Reduce Maintenance ?	Yes !
Retrofit To Reduce Bromate ?	Yes !



Water Research Foundation Project No. 4588

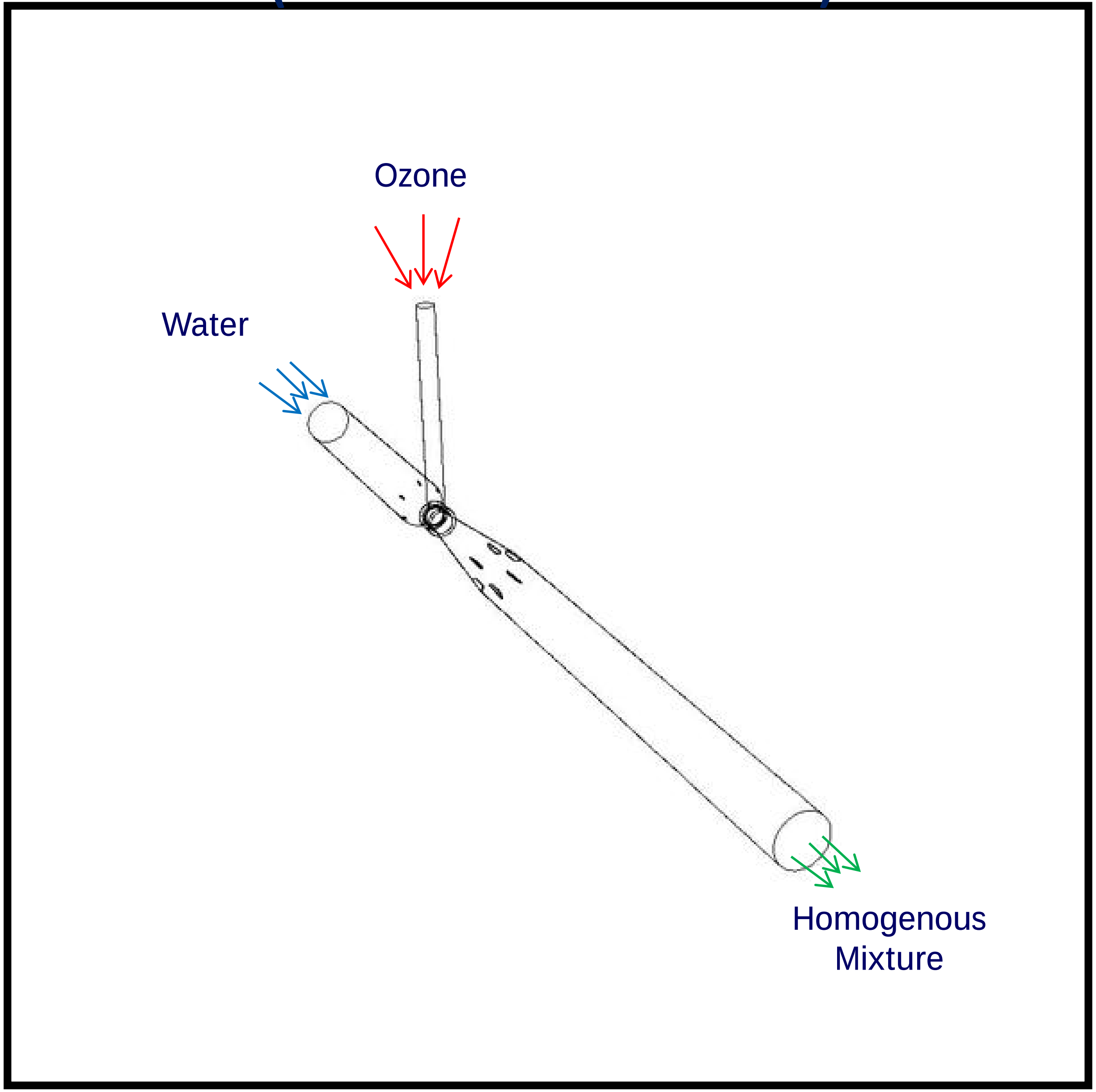
Venturi

Gas Injection

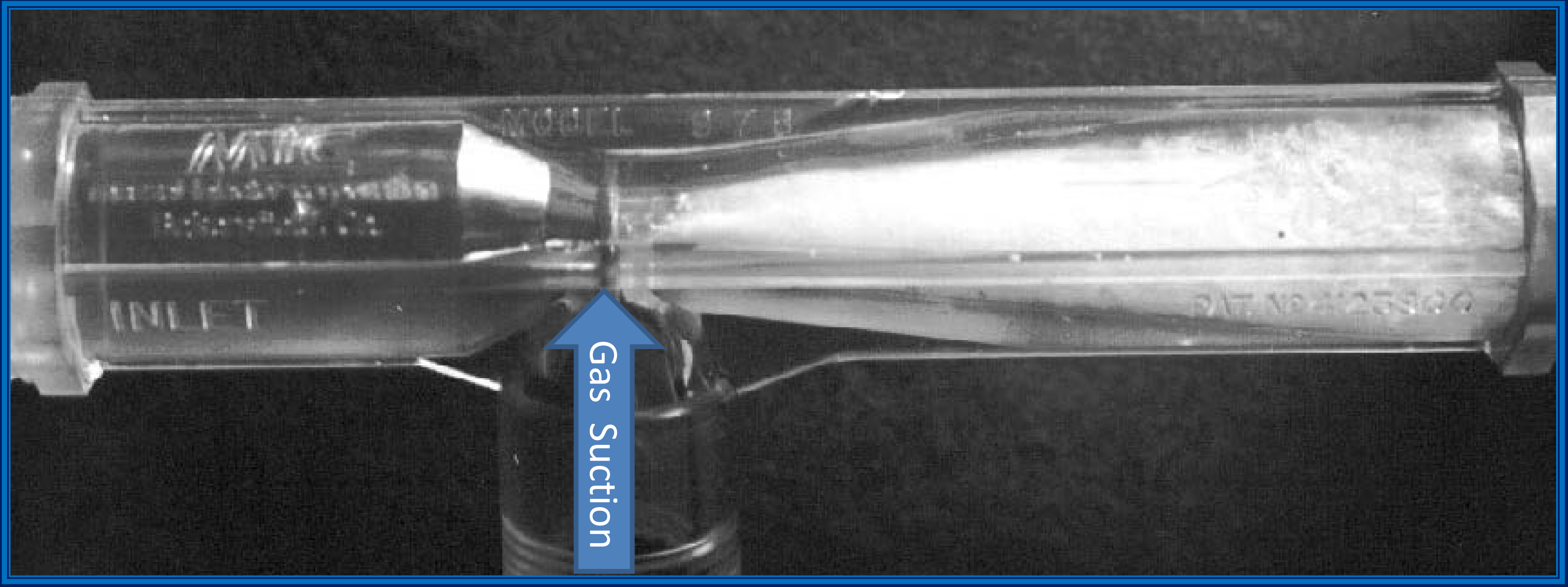
VENTURI GAS INJECTORS

VENTURI GAS INJECTION SKIDS

Stage 1 of Ozone Transfer
(CFD Driven Simulation)



VENTURIE GAS INJECTOR




INLET
PRESSURE
4" OS 60 psi
JAMESBURY

Injector Inlet Pressures Determines Water Flow Rate

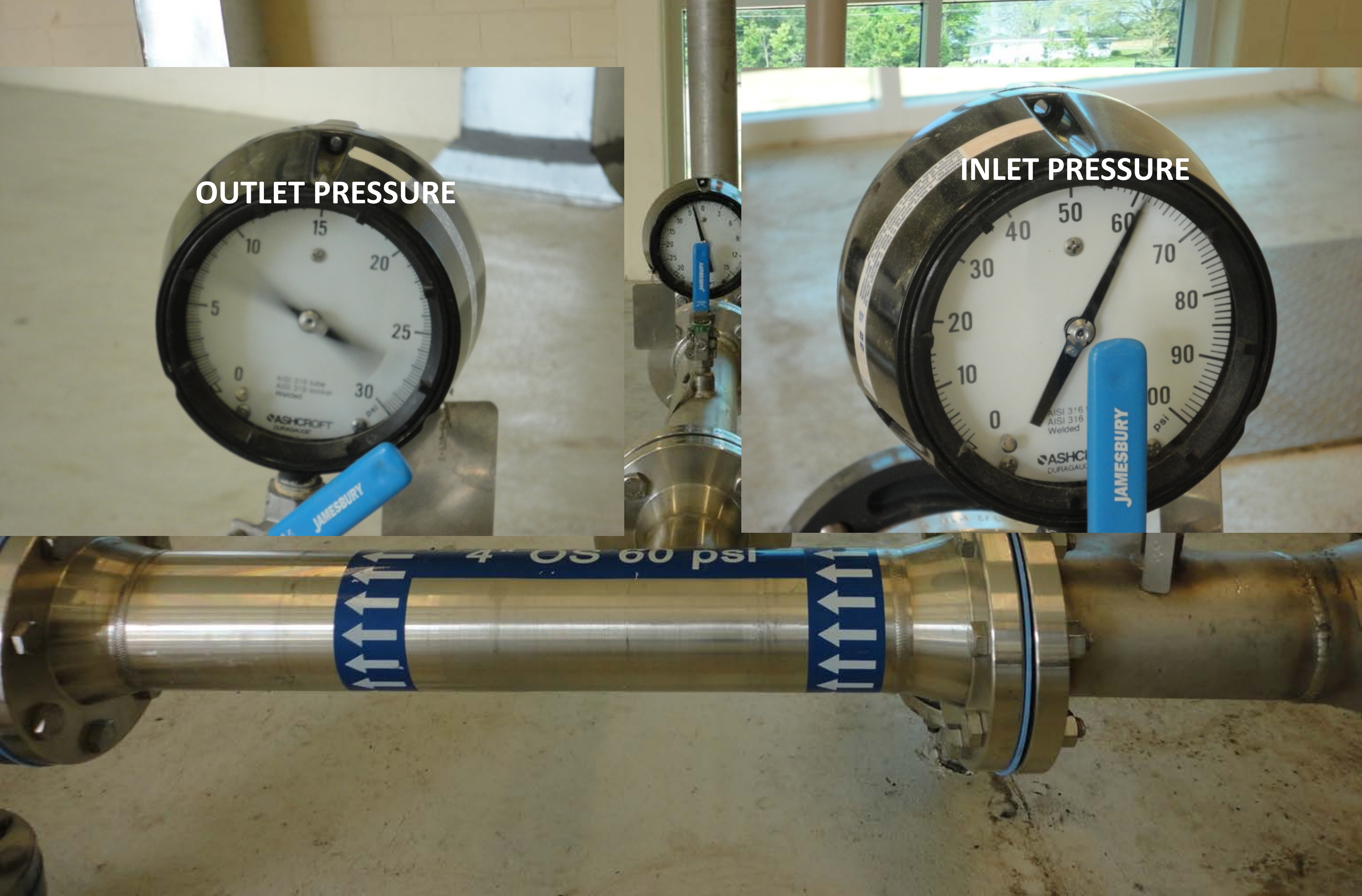
Mazz… …ble

Injector Model **3090** 7/23/2004

Operating Pressure PSIG			Air Suction	
Injector Inlet	Injector Outlet	[redacted]	Motive Flow GPM	Air Suction SCFM
5	0		73	
	1			
	2			
	3			
	4			
10	1		103	11.9
	2			10.6
	5			6.3
	7			4.9
	8			0.5
15	2		127	16.4
	5			11.2
	7			7.0
	10			4.4
	12			2.0
20	2		146	19.0
	5			14.2
	10			6.5
	12			4.9
	15			3.6
25	2		164	20.7
	5			16.7
	10			9.0
	15			5.2
	20			1.0
30	2		179	22.9
	5			19.0
	10			11.3
	15			6.4
	20			4.2
	25			0.0
	2			24.2

Operating Pressure PSIG			Air Suction	
Injector Inlet	Injector Outlet	[redacted]	Motive Flow GPM	Air Suction SCFM
50	2		231	25.8
	10			19.5
	15			13.1
	20			9.1
	25			7.1
	30			5.1
	35			3.8
	40			Trace
60	2		253	28.5
	10			21.6
	20			10.5
	25			8.0
	30			6.9
	35			5.2
	40			3.7
	45			2.0
70	2		274	30.2
	10			25.3
	20			13.7
	30			9.6
	35			7.4
	40			5.4
	45			4.2
	50			3.3
	55			1.5
80	2		293	33.0
	20			18.5
	30			11.6
	35			9.6
	40			8.3
	45			6.3
	50			4.3

PRESSURE DIFFERENTIAL SETS GAS SUCTION



Injector Pressure Differential Determines Gas Suction

Injector Mo [redacted] **3090** 7/23/2004

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	2			24.2

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	55			1.5
80	2		293	33.0
	20			18.5
	30			11.6
	35			9.6
	40			8.3
	45			6.3
	50			4.3

VENTURI INJECTOR OPERATION

INCREASING GAS FEED PRESSURE INCREASES INJECTOR GAS CAPACITY

Basin MGD	Ozone SCFM	NO. Inj	Inj SCFM	Injector Model	Inlet PSIG	O3 PSIG	Flow GPM	Outlet PSIG	Pump BHP	Pump Rated HP
45	105.27	2	52.6	4091	40	6	345	10	10.7	15
	45.12	1	45.1			3	356	10	11.0	15
20	46.79	1	46.8			4	351	10	10.9	15
	20.05	1	20.1			0	371	10	11.5	15

VENTURI INJECTOR OPERATION

…BUT DECREASES THE INJECTOR FLOW RATE

Basin MGD	Ozone SCFM	NO. Inj	Inj SCFM	Injector Model	Inlet PSIG	O3 PSIG	Flow GPM	Outlet PSIG	Pump BHP	Pump Rated HP
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	45.12	1	45.1			3	356	10	11.0	15
20	46.79	1	46.8			4	351	10	10.9	15
	20.05	1	20.1			0	371	10	11.5	15

SECONDARY GAS MIXING DEVICE

- Basin Nozzle Manifold

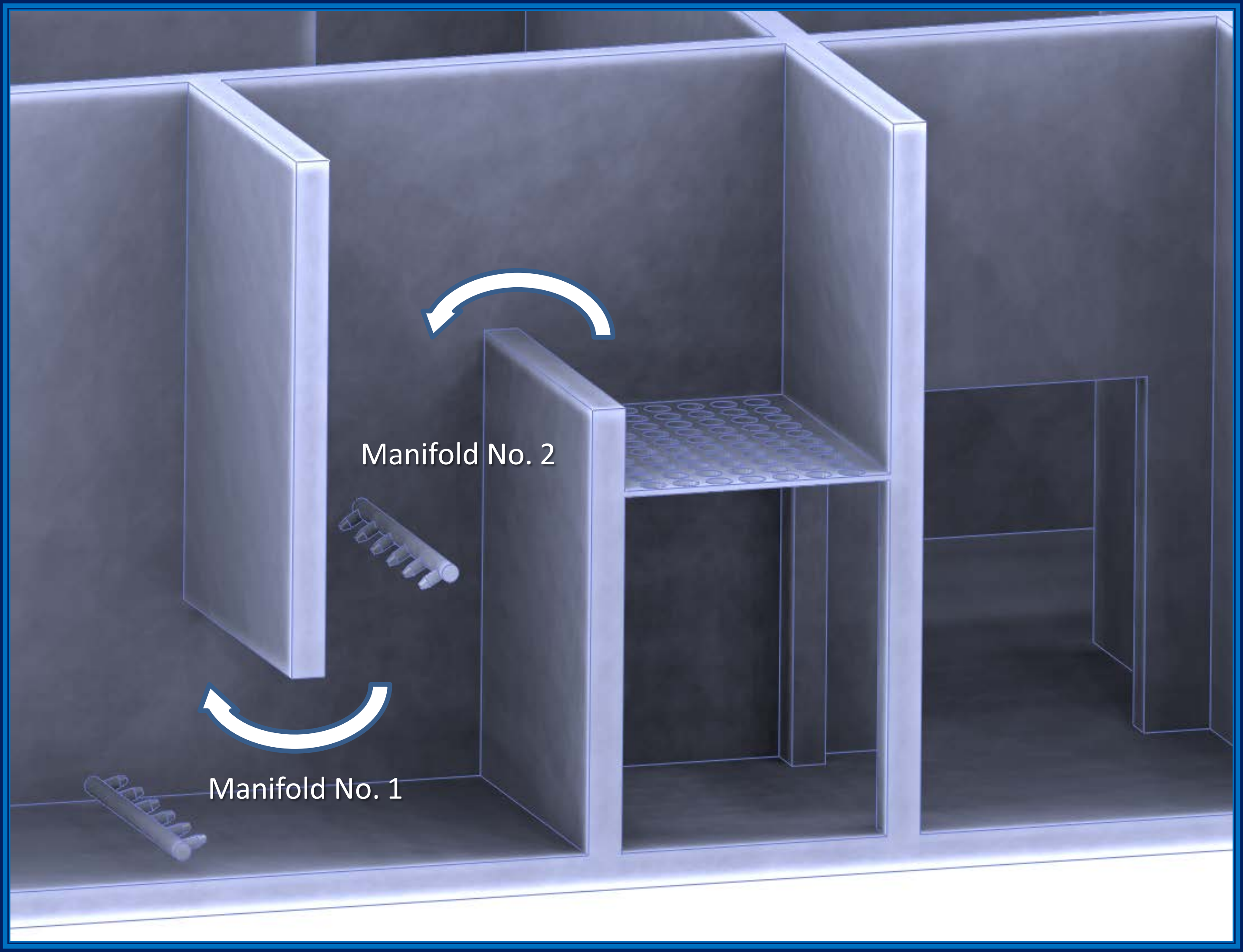
Basin Nozzle Manifold

Stage 2 Of Gas Transfer

BASIN NOZZLE MANIFOLDS

Stage 2 of Gas Transfer

Dual Basin Nozzle Manifold
Dublin Road WTP
Columbus, OH



Dual Basin Nozzle Manifold
Dublin Road WTP
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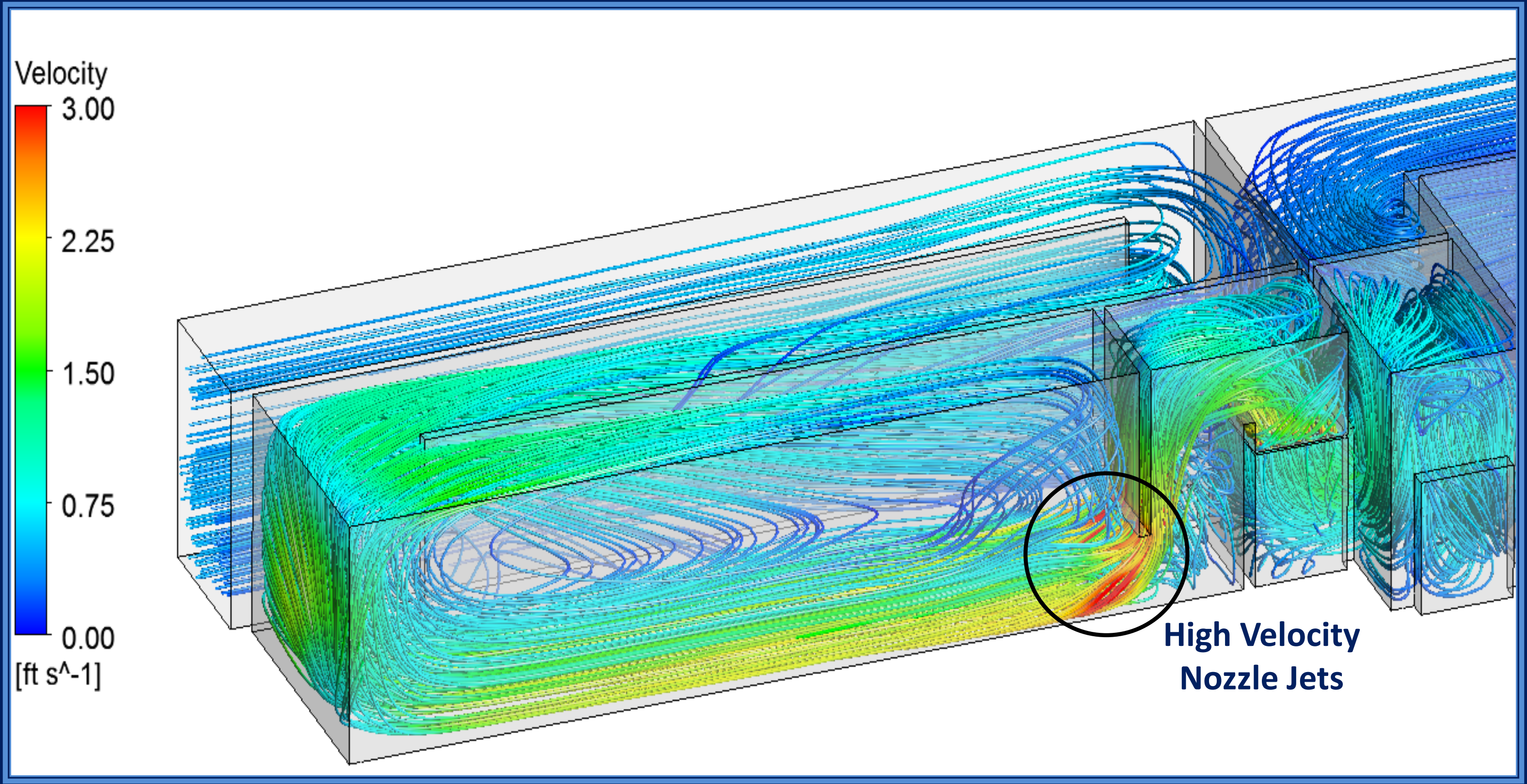
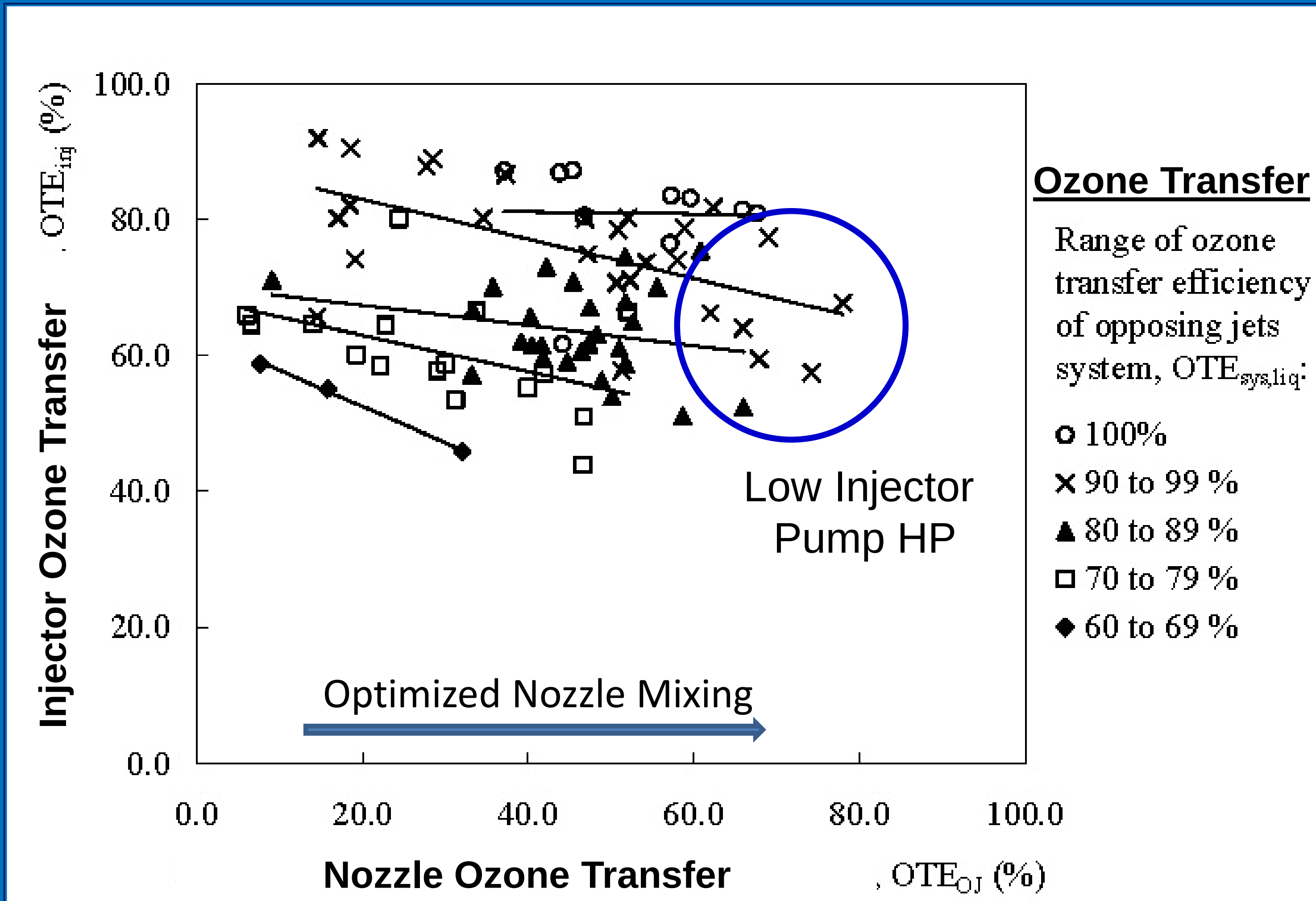


Dublin Road WTP, Columbus, OH -Isometric view of velocity streamlines at larger velocity scale

CFD Courtesy Dr. William Bellamy CH2M

2-Stage Ozone Transfer



Ozone Mass Transfer of an Injector with an Opposing Jets Reactor, A. Bale, et al, IOA PAG 2003

CASE
HISTORY

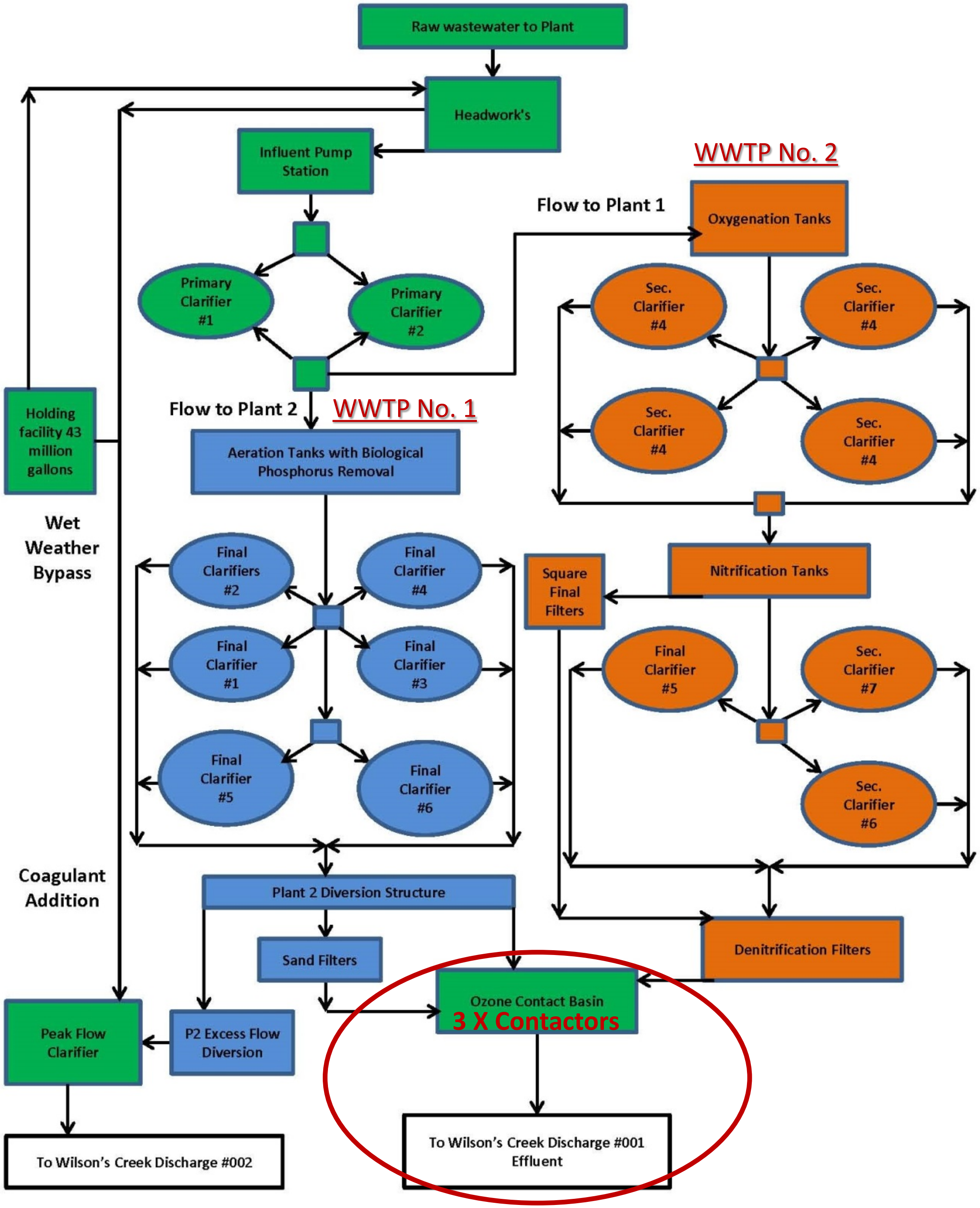
WASTEWATER DISINFECTION
&
REUSE

Southwest WWTP

Springfield, MO USA

SOUTHWEST WWTP

- Continuously using ozone disinfection since 1978
- 50 Ton cryogenic oxygen plant + plate ozone generators
- Replaced O3 generators in 1988: Emery 1,800 ppd @ 3% wt.



O3 Disinfection Targets

- E. Coli: $\leq$ 126 MPN/ml (Daily)
- Fecal Colifom: $\leq$ 200 MPN/ml (Mo. Avg.)

OZONE GENERATON SYSTEM
2008 MAINTENANCE COST

> $ 95,000 / Yr. !

OZONE SYSTEM UPGRADE

EXISTING	UPGRADE
• 50 Ton Cryogenic Oxygen Plant	• 50 Ton Cryogenic Oxygen Plant
• Emery Gen: 3 X 800 PPD	• Mitsubishi: 2 x 2,800 PPD
• O3 Conc.: 3 - 3.5 % wt.	• O3 Conc.: 4 – 10 % wt.
• Three Ozone Contact Basins	• Three Ozone Contact Basins
– O3 Turbine Mixers: 9 x 30 HP	– O3 SVI: 2 x 60 HP pumps
– Min to Average PPD: 270 HP	– Min to Average PPD: 60 HP
– Max PPD: 270	– Max PPD: 120 HP

SOUTHWEST WWTP

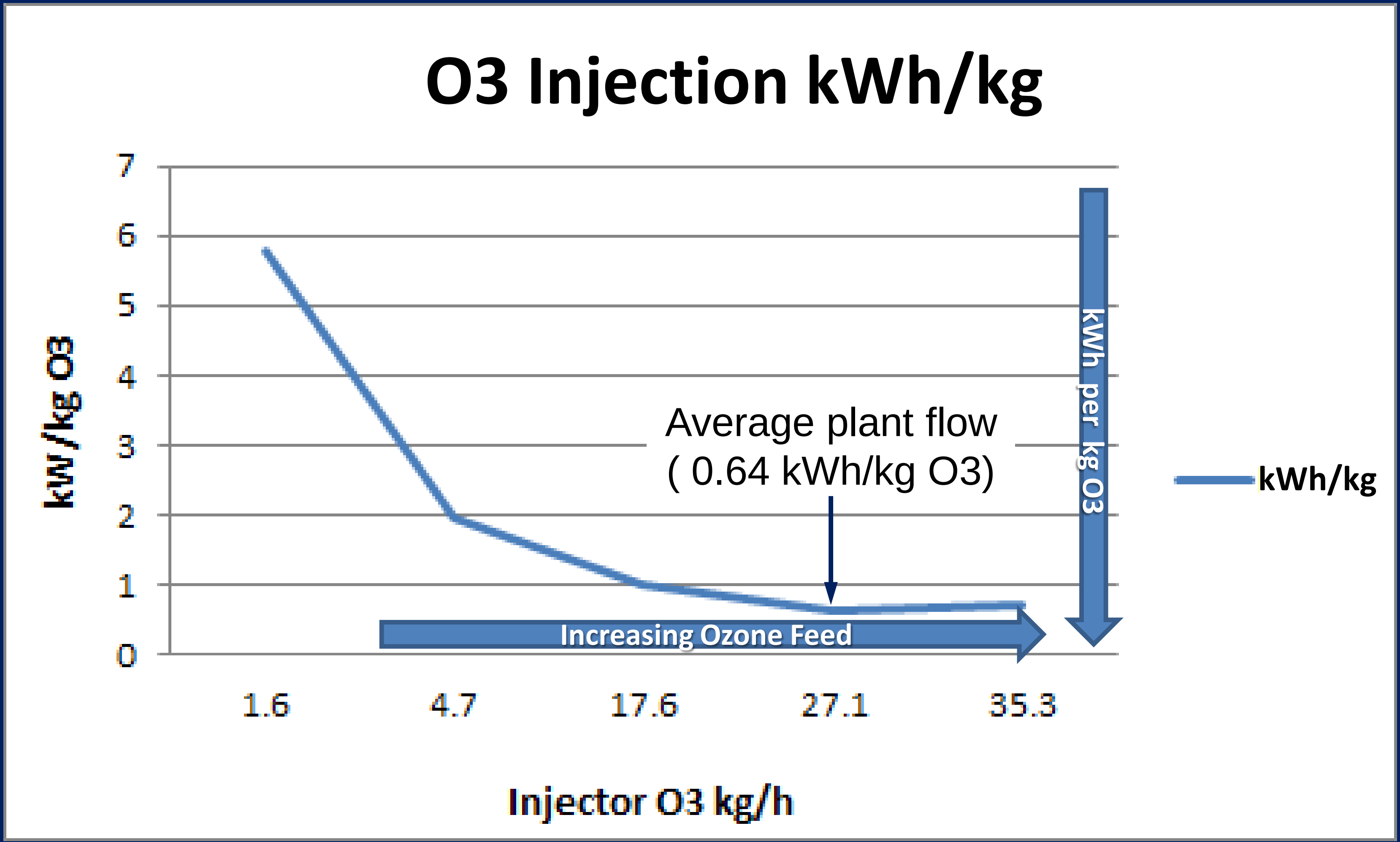
Contact Basin Gas Injection Retrofit

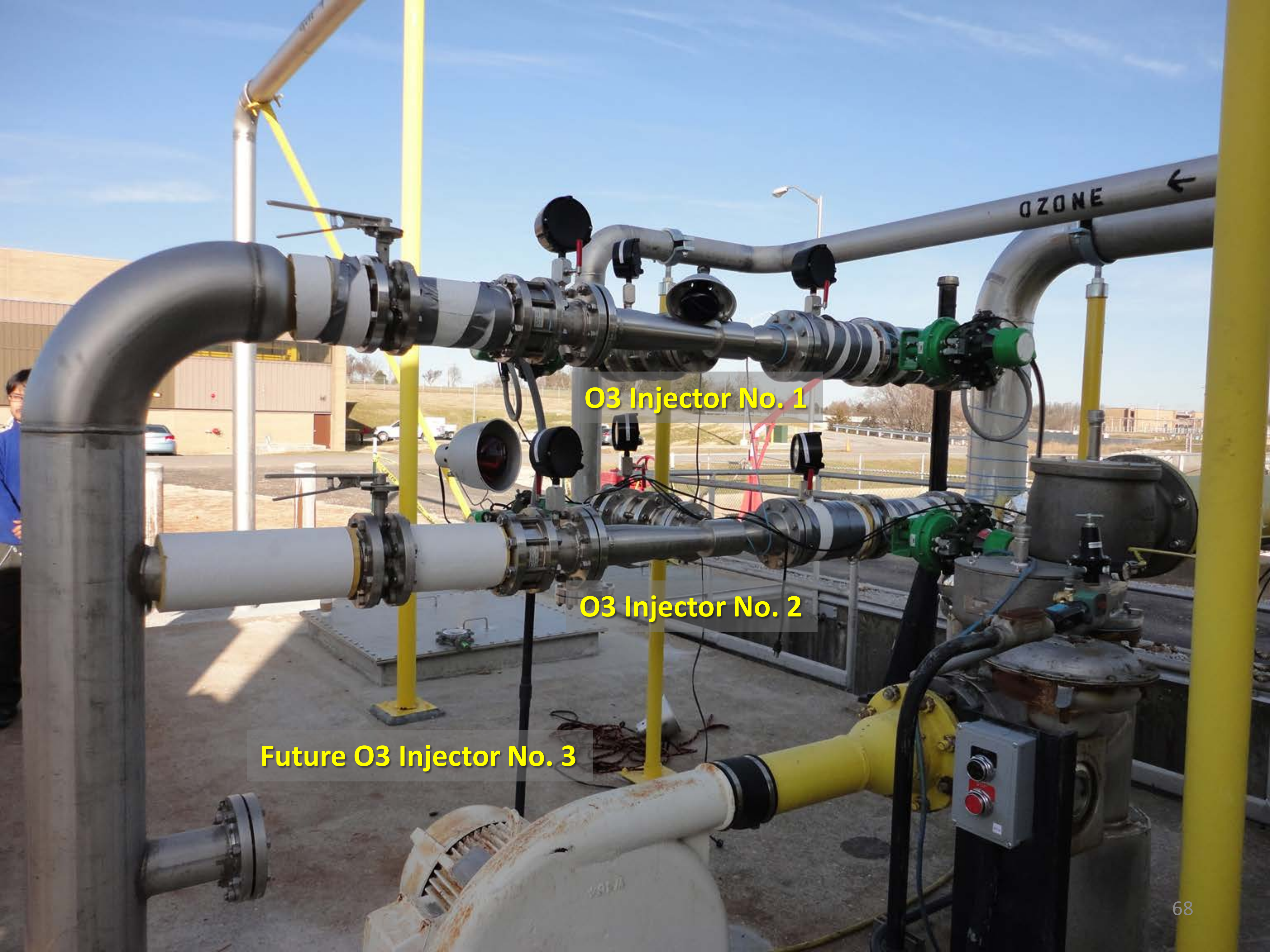
Minimizing Injector Pump HP

Basin Operation	Basin MGD	Basin O3 lbs/d	Basin O3 SCFM	No. Injectors	Inj. O3 lbs/d	Inj. O3 SCFM	Inj. Model	Inj. Inlet PSIG	O3 Feed PSIG	Injector Flow GPM	Inj. Outlet PSIG	Inj. Capacity O3 SCFM
Future	53.3	1,868	606	3	622.6	70.0	4091	40	6	339	10	73.5
Peak	33.3	1,434	328	2	716.9	58.8			4	351	8.8	59
Max	21.3	931	303	2	465.6	52.5			4	351	8.7	59
Avg	3.7	249	82	1	248.7	28.4			0	371	2.5	44
Min	5	85	2	1	84.7	16.7			0	371	2	47

SW WWTP O3 INJECTION RETROFIT

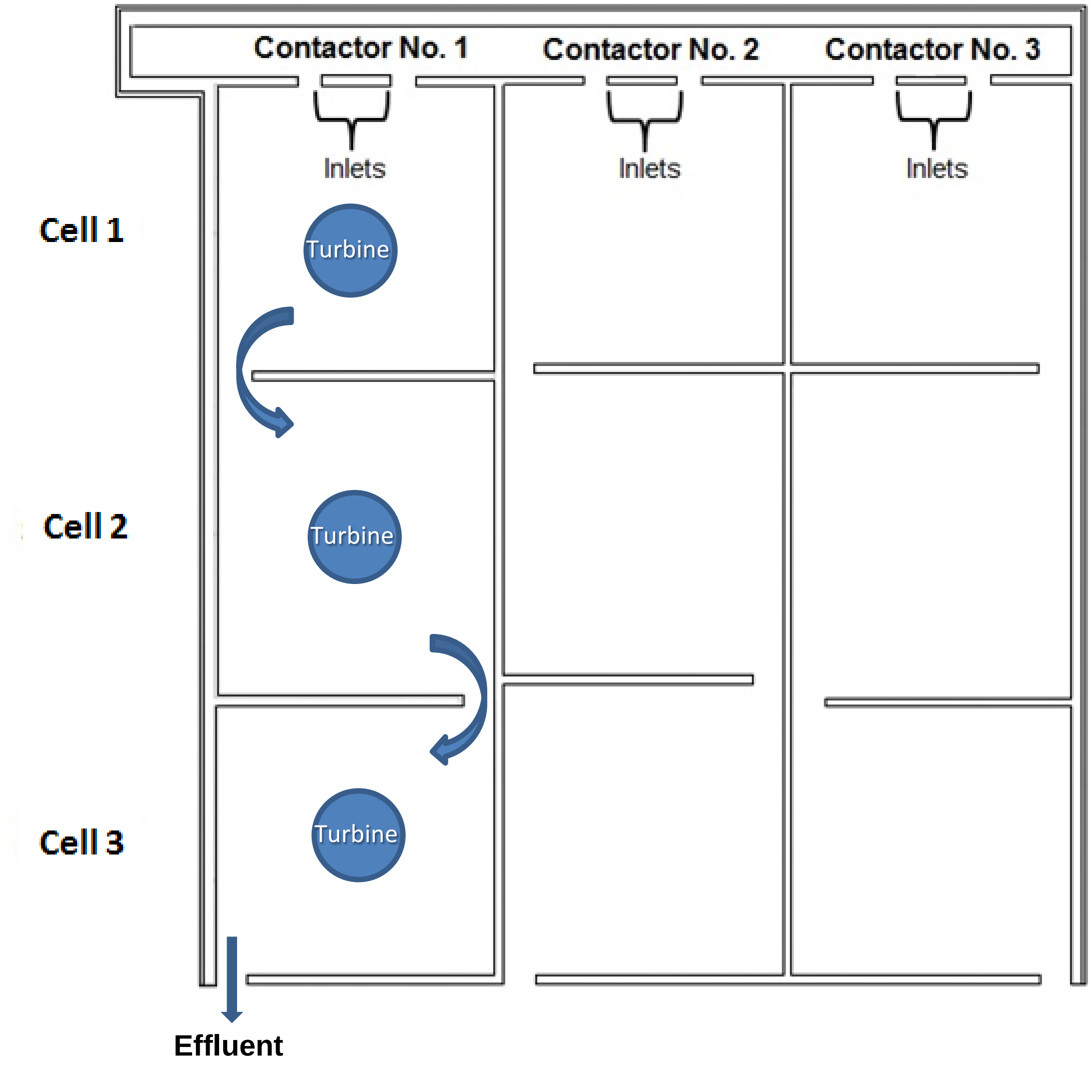
Contact Basin Energy Cost



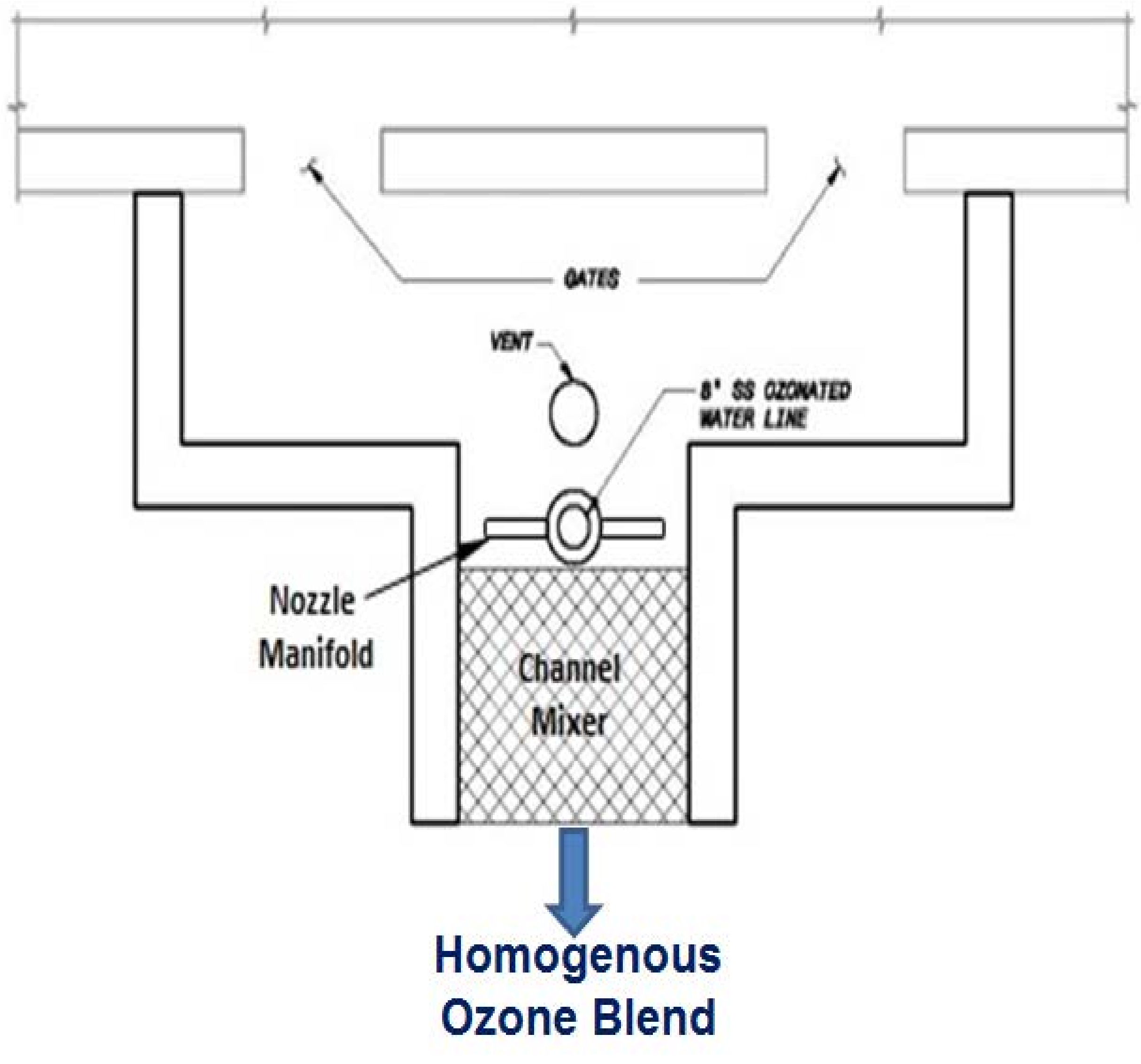

OZONE
O3 Injector No. 1
O3 Injector No. 2
Future O3 Injector No. 3

Ozone Contact Basin

Retrofit Challenge

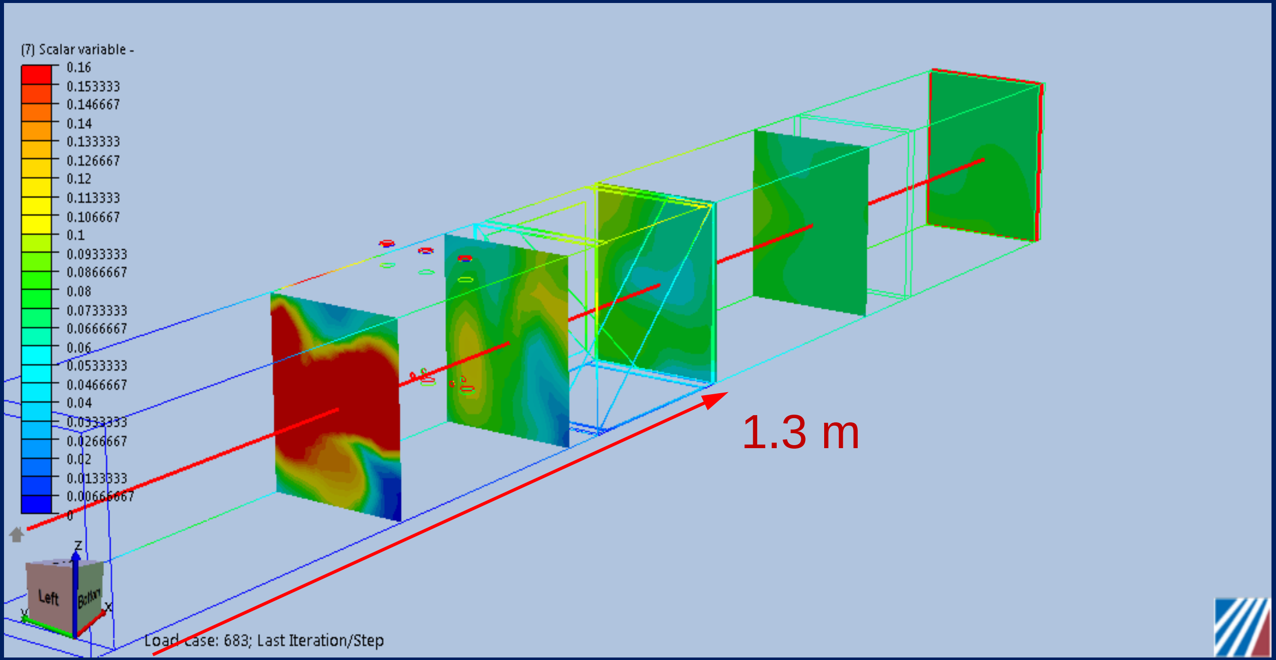


Basin Inlet Modification



SOUTHWEST WWTP

Min Flow Channel CFD



Low Flow - 5 MGD concentration contours at the different cross sections

SOUTHWEST WWTP

Injection Retrofit Energy Savings

O3 TRANSFER (Average): 88 % @ 750 PPD - 6.1% wt. O3

Plant Flow Condition	Ozone Production (PPD)	Daily Pump (kW hrs)	SVI-BNM Energy (kWh/ppd O3)	Daily Turbine (kW hrs)	Turbine Energy (kWh/ppd O3)	SVI-BNM Energy Savings (kWh/d)
Average	750	664.2	0.89	3,865.7	4,365.4	3,201.6
Maximum	2800	1,328.3	0.47	3,865.7	8,148.7	2,537.4
Storm	4300	1,328.3	0.31	3,865.7	12,514.1	2,537.4

Note: kWh based on motor brake hp @ 80% motor efficiency


WWTP OUTFALL
WATER REUSE
Local Power Generation Utility Using
Plant Effluent for Cooling Water

Southwest Clean Water Plant

Springfield, MO USA

SECONDARY GAS MIXING DEVICE

- Pipeline Flash Reactor (PFR)

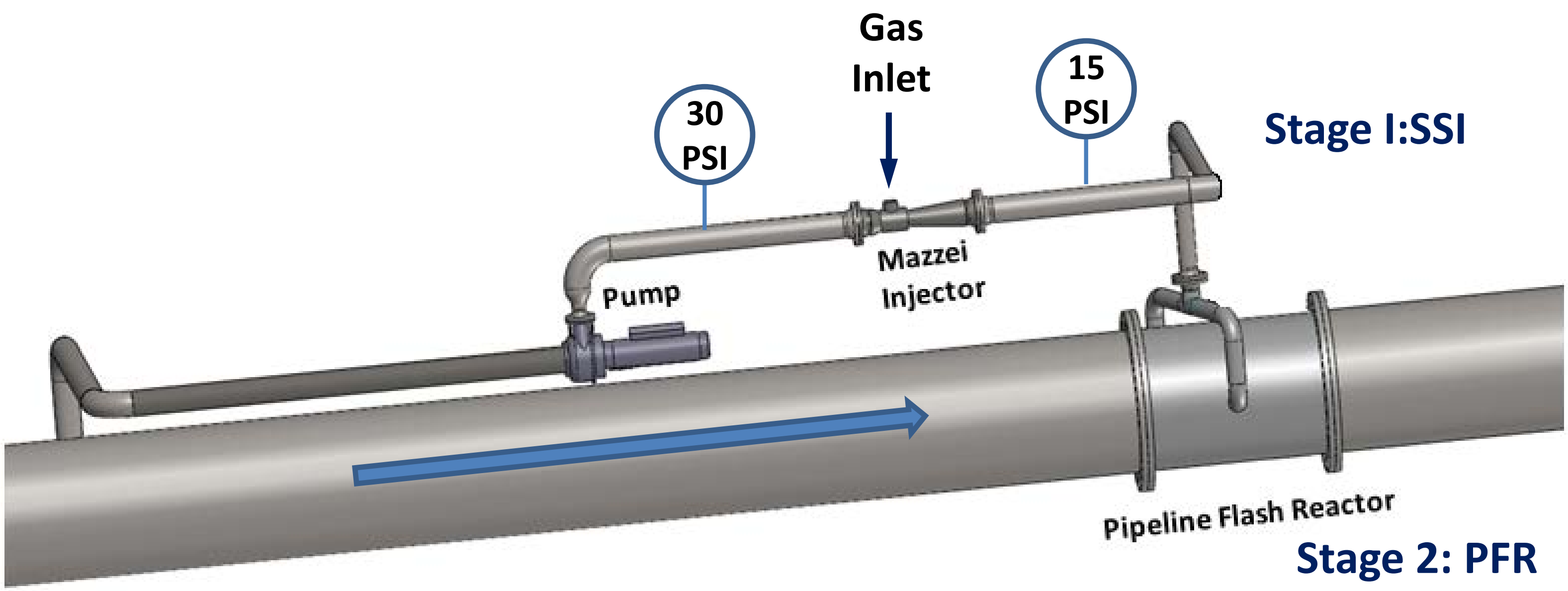
PIPELINE FLASH REACTOR

PIPELINE FLASH REACTOR

Stage 2 of Gas Transfer

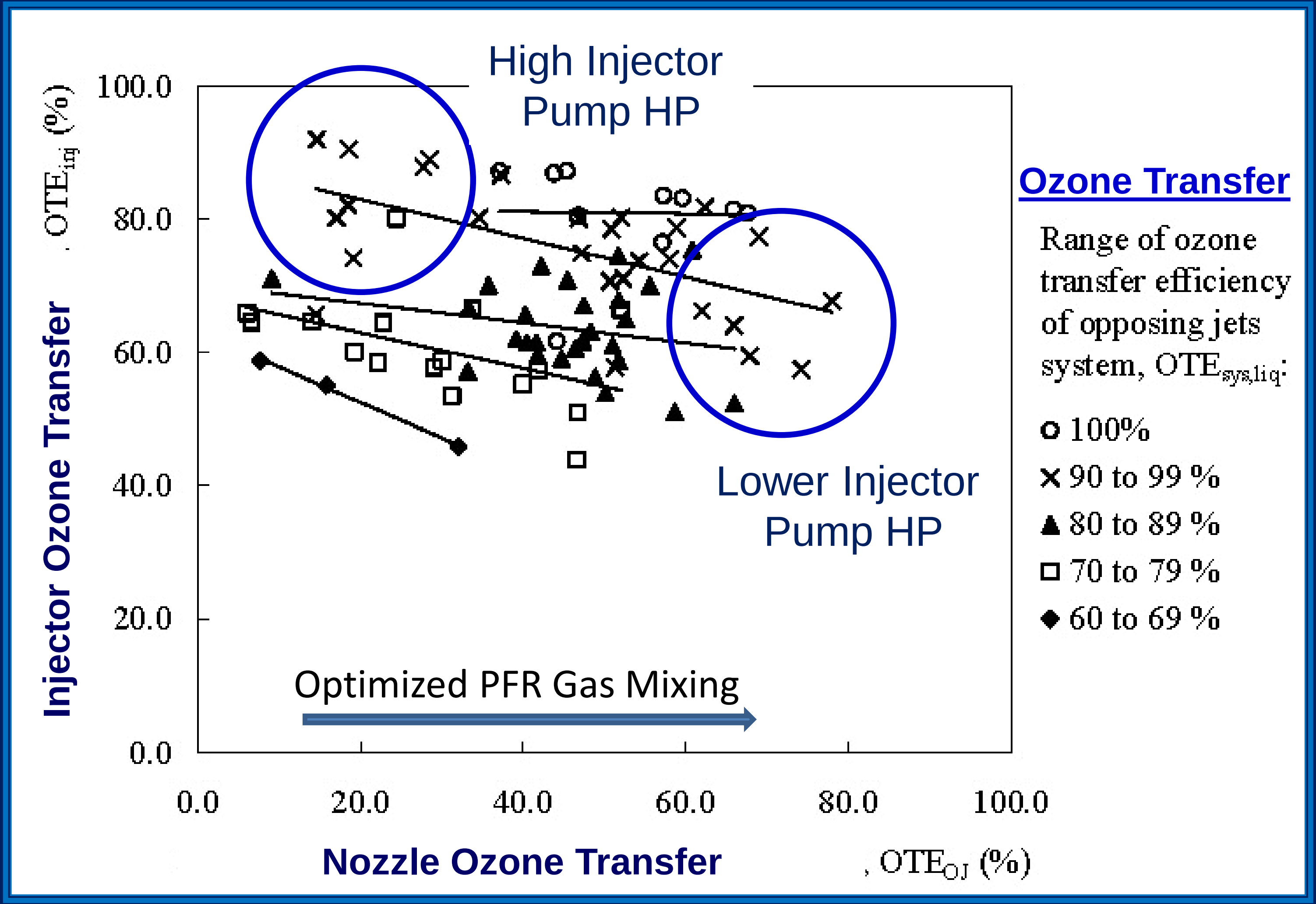
SIDESTREAM GAS INJECTION

Pipeline Flash Reactor



A 2- Stage Transfer of Gas to Solution.

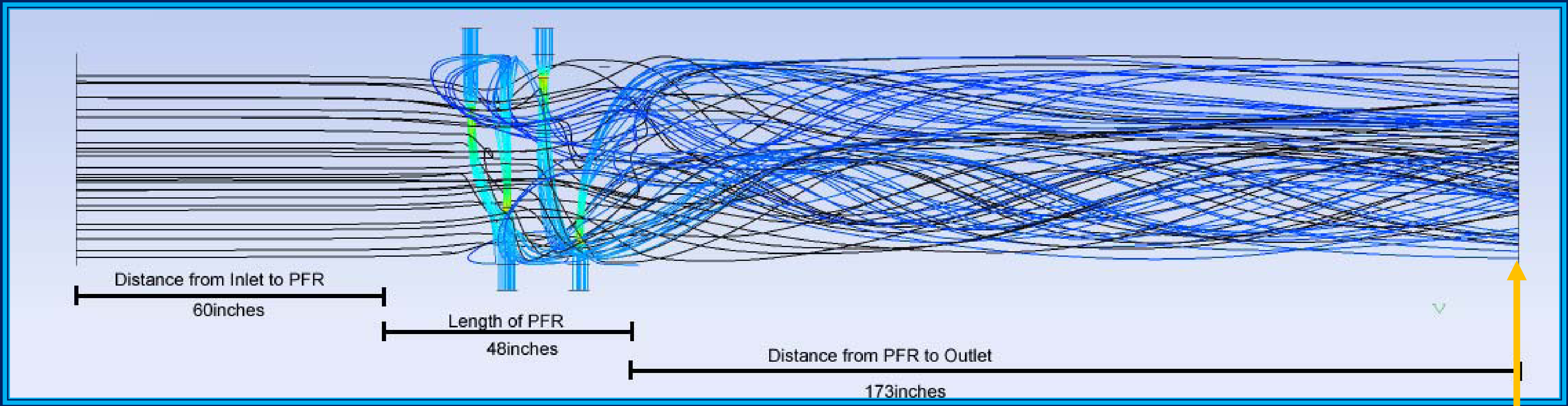
2-Stage Ozone Transfer



Ozone Mass Transfer of an Injector with an Opposing Jets Reactor, A. Bale, et al, IOA PAG 2003

OPTIMIZING PFR PERFORMANCE

Computational Fluid Dynamics

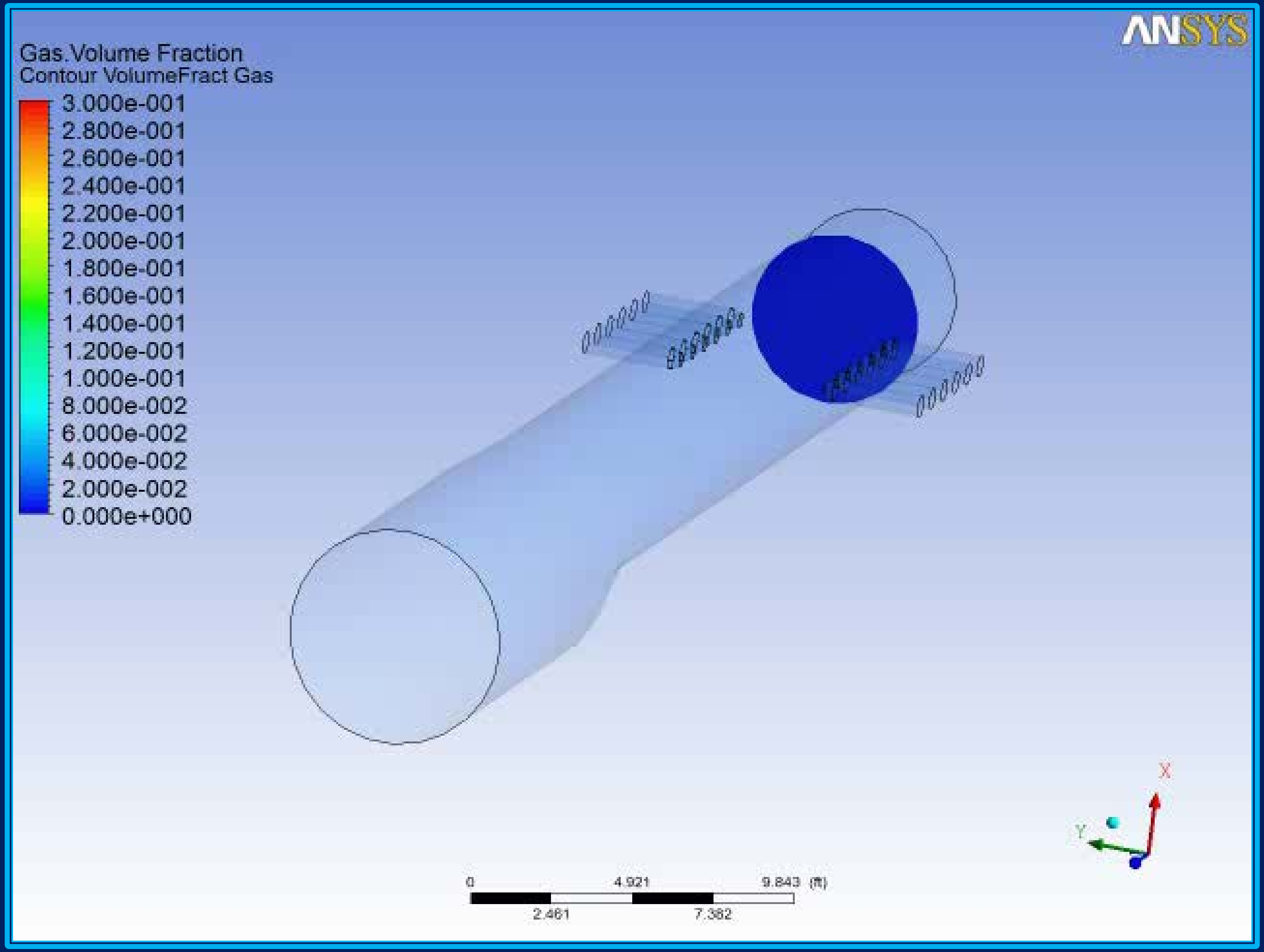


Buckingham WTP PFR, Gatineau, QC Canada

Homogenous Blend
C o V ≤ 5 %

OPTIMIZING PFR PERFORMANCE

Computational Fluid Dynamics



CASE
HISTORY

GROUND WATER OXIDATION

ORLANDO UTILITY COMMISSION
SW WTP

Commission Date: 1997
Peak Water Production: 45.6 MGD
Water Quality Issue: T & O (H_2S)
Water Source: Ground Water (5 wells)
Initial Treatment: O_3 + Cl_2


OZONE
GENERATOR
UNIT #4
DANGER
HIGH VOLTAGE
Air Fed Ozone Generators

Spare parts availability
Operating costs:
-LOX Vs Elect. Power

OUC SW WTP

ORIGINAL DESIGN 1997-2000	OZONE UPGRADE 2014
O3 On Site: 4 x 950 ppd	O3 On Site: 3 x 1,260 ppd
O3 Generator Feed Gas: Air	O3 Generator Feed Gas: O2
Peak O3 Flow: 1,600 SCFM	Peak O3 Flow: 382 SCFM
No. Contactors: 3	No PFRs: 1
No. Gas Diffusion Stones: 1,656	No. Gas Injectors: 5
Confine Space Entry: Yes	Confine Space Entry: 1
Maintenance: Clean or replace diffusers and gaskets bi-annually.	Maintenance: Clean or replace injector gas check valves annually.

OUC SW WTP

ORIGINAL DESIGN 1997-2000

- O3 On Site: 4 x 950 ppd
- O3 Generator Feed Gas: Air
- Peak O3 Flow: 1,600 SCFM
- No. Contactors: 3
- No. Gas Diffusion Stones: 1,656
- Confine Space Entry: Yes
- Maintenance: Clean or replace diffusers and gaskets bi-annually.

OZONE UPGRADE 2014

- O3 On Site: 3 x 1,260 ppd
- O3 Generator Feed Gas: O2
- Peak O3 Flow: 382 SCFM
- No PFRs: 1
- No. Gas Injectors: 5
- Confine Space Entry: 1
- Maintenance: Clean or replace injector gas check valves annually.

Safety
Maintenance requirements

OZONE SYSTEM DESIGN PARAMETERS

Design Criteria	Units [1]	Value
Average Day Flow	MGD	26.6
Maximum Day Flow (wellfield capacity)	MGD	45.6
Permitted Max Day Flow (2023 CUP Allocation)	MGD	39.9
Minimum Day Flow (2 wells operating)	MGD	10.4
Minimum Day Flow (3 wells operating)	MGD	17.4
Average Ozone Dose	mg/L	8.4
Maximum Ozone Dose	mg/L	9.84
Minimum Ozone Dose	mg/L	7.4
Average Ozone Production	ppd	1,862 @ 12%
Maximum Ozone Production (45.6 MGD)	ppd	3,740 @ 8%
Maximum Ozone Production (39.9 MGD)	ppd	3,272 @ 9.5%
Minimum Ozone Production (2 wells)	ppd	644 @ 12%
Minimum Ozone Production (3 wells)	ppd	1,079 @ 10%

Ozone Dissolution Modifications and Feed Gas Conversion from Air Prep to LOX in Orlando Fl, Greg Taylor et. al, IOA IUVA World Congress, Las Vegas, NV Sept 2013

INJECTION SYSTEM DESIGN

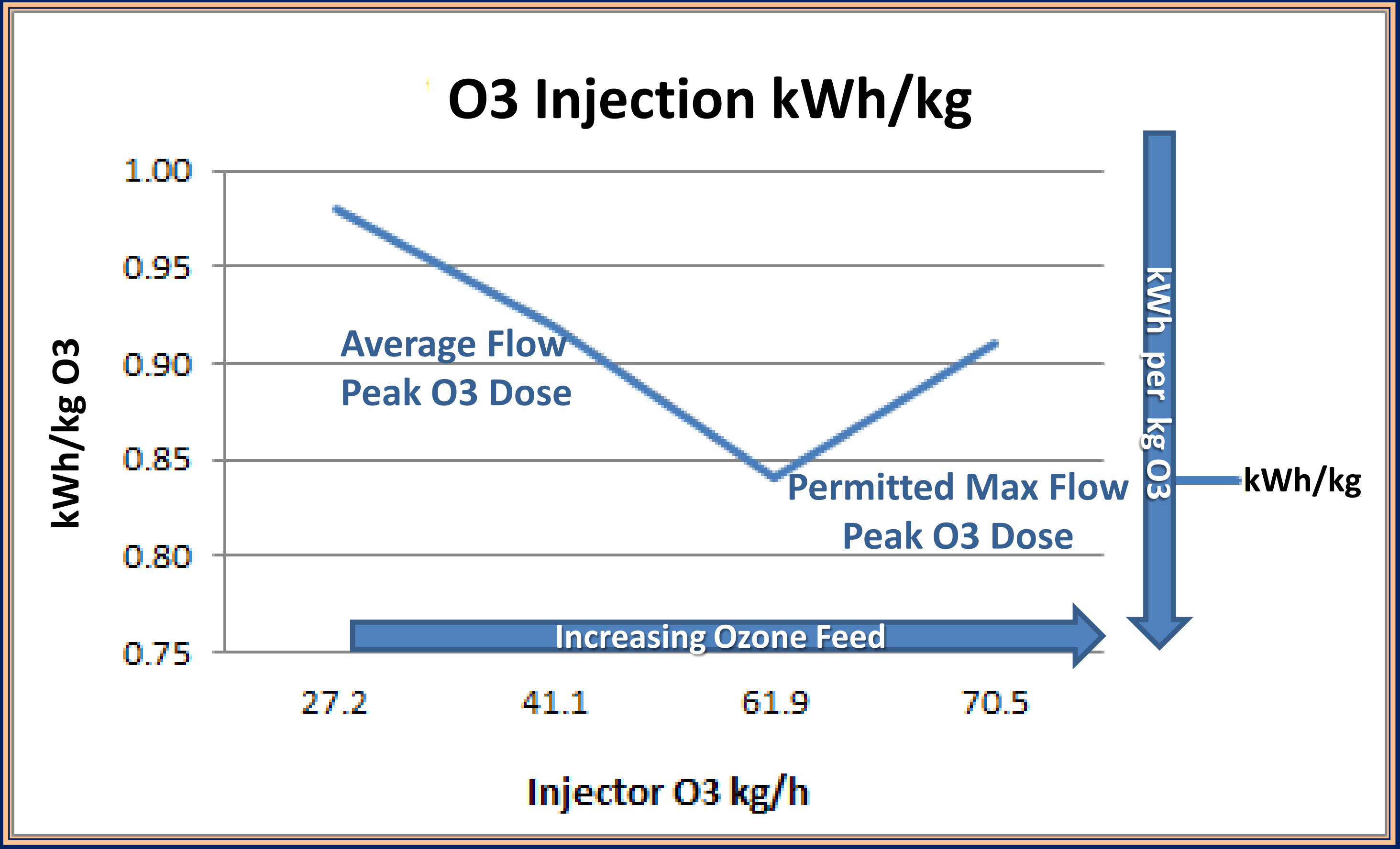
Minimizing Injector Pump HP

Plt MGD	Plt GPM	O3 kg/Hr	O3 SCFM	Duty PFRs	PFR SCFM	No Inj	Inj SCFM	Inj Model	Inj. Inlet PSIG	Inj. O3 PSIG	Inj Wtr GPM	Inj. Outlet PSIG	Inj. Design SCFM	Inj Pump BHP*	Total PFR BHP	Plant Total BHP	O3 % TE
45.6	31,667	70.5	376.0	1	376.0	5	75.2	4091	55	5	421	12	82.4	17.3	86.4	86.4	≥ 96
		60.4	322.3		322.3		64.5			3	426		66.9	17.5	87.4	87.4	
		53.2	283.9		283.9		56.8			2	431		59.6	17.7	88.5	88.5	
39.9	27,708	61.9	276.7	1	276.7	4	69.2			4	424		74.4	17.4	69.6	69.6	
		52.9	236.2		236.2		59.1			3	426		66.9	17.5	70.0	70.0	
		46.6	208.1		208.1		52.0			2	431		59.6	17.7	70.8	70.8	
26.6	18,472	41.1	144.2	1	144.2	3	48.1			1	433		52.8	17.8	53.3	53.3	
		35.2	123.6		123.6		41.2			0	436		47	17.9	53.7	53.7	
		31.0	108.9		108.9		36.3		55	0	436		47	17.9	53.7	53.7	
										Pump Design Pt							
17.6	12,222	27.2	95.4	1	95.4	2	47.7			1	433		52.8	17.8	35.6	35.6	
		23.3	81.8		81.8		40.9			0	436		47	17.9	35.8	35.8	
		20.5	72.0		72.0		36.0			0	436		47	17.9	35.8	35.8	

*Pump NPSH = 5 psig + 70 % Pump Eff.

INJECTION SYSTEM DESIGN

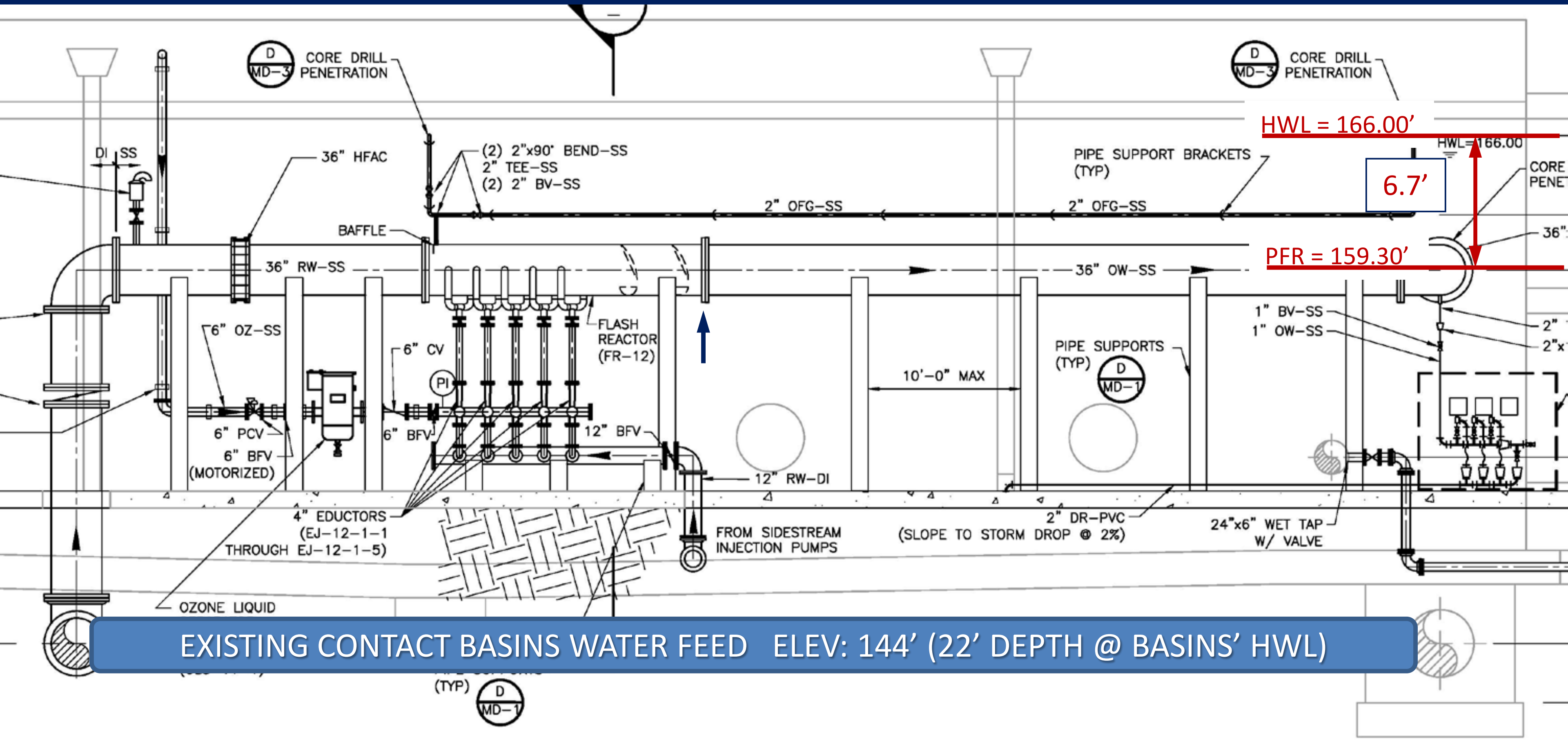
-Energy Cost-



SW WTP
OZONE TRANSFER CHALLANGE

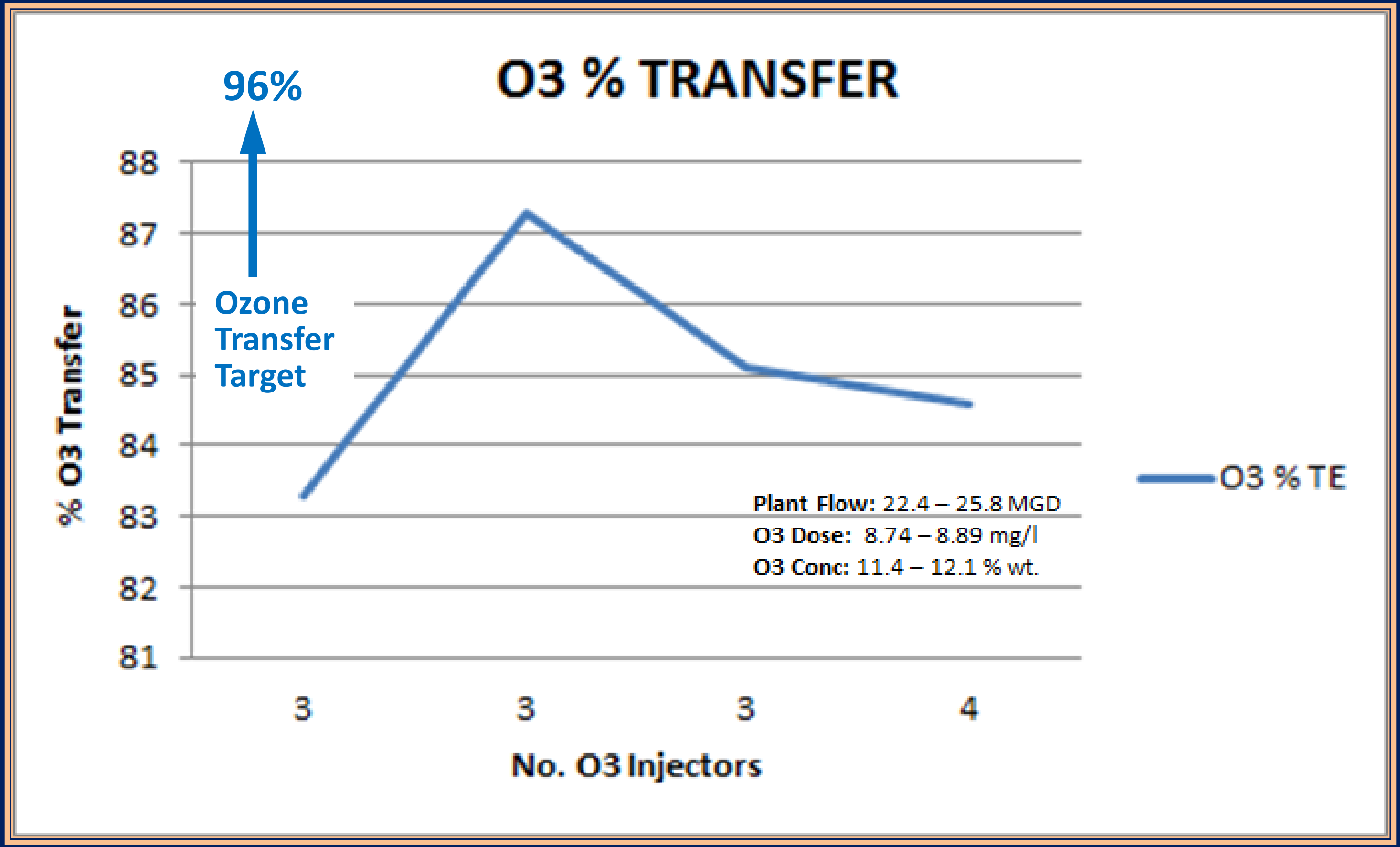
- Gas Injection: 5 Sets of nozzle jets in 80 " of water.
- Max Design O3 Dose: 9.8 mg/l
- Peak O3 Dose: $\geq$ 9.0 mg/l
- Injector G/L: $\geq$ 0.8
- Max Water Temperature: 25 C
- Historical Performance: 1,656 diffusion stones in 22 ' water

PIPELINE FLASH REACTOR LOCATION



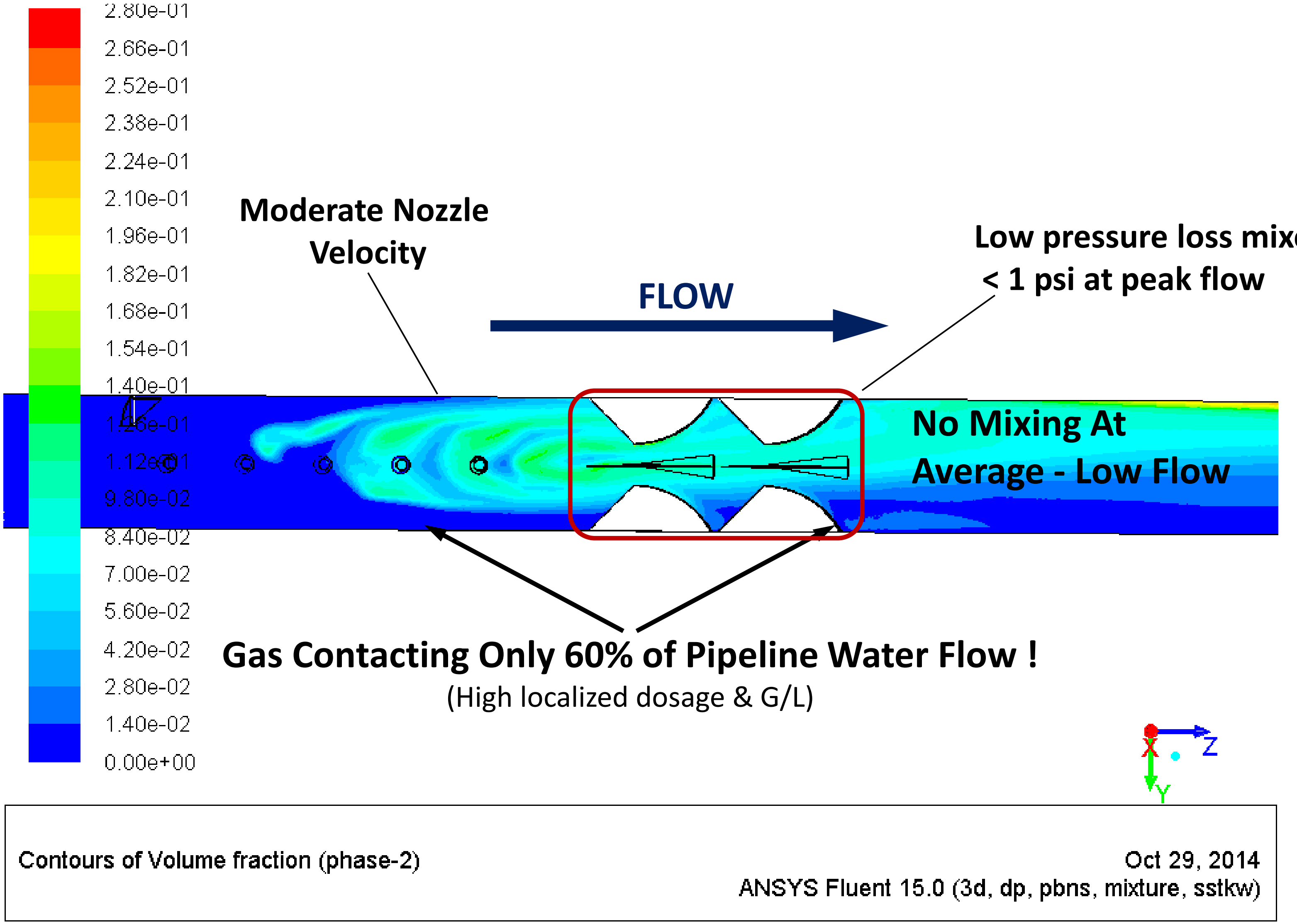
OUC SW WTP INJECTION SYSTEM LAYOUT

COMMISSIONING INJECTION SYSTEM



Case 1: Specified Injector, PFR and Mixer

26.6 MGD & 3 Gas Injectors

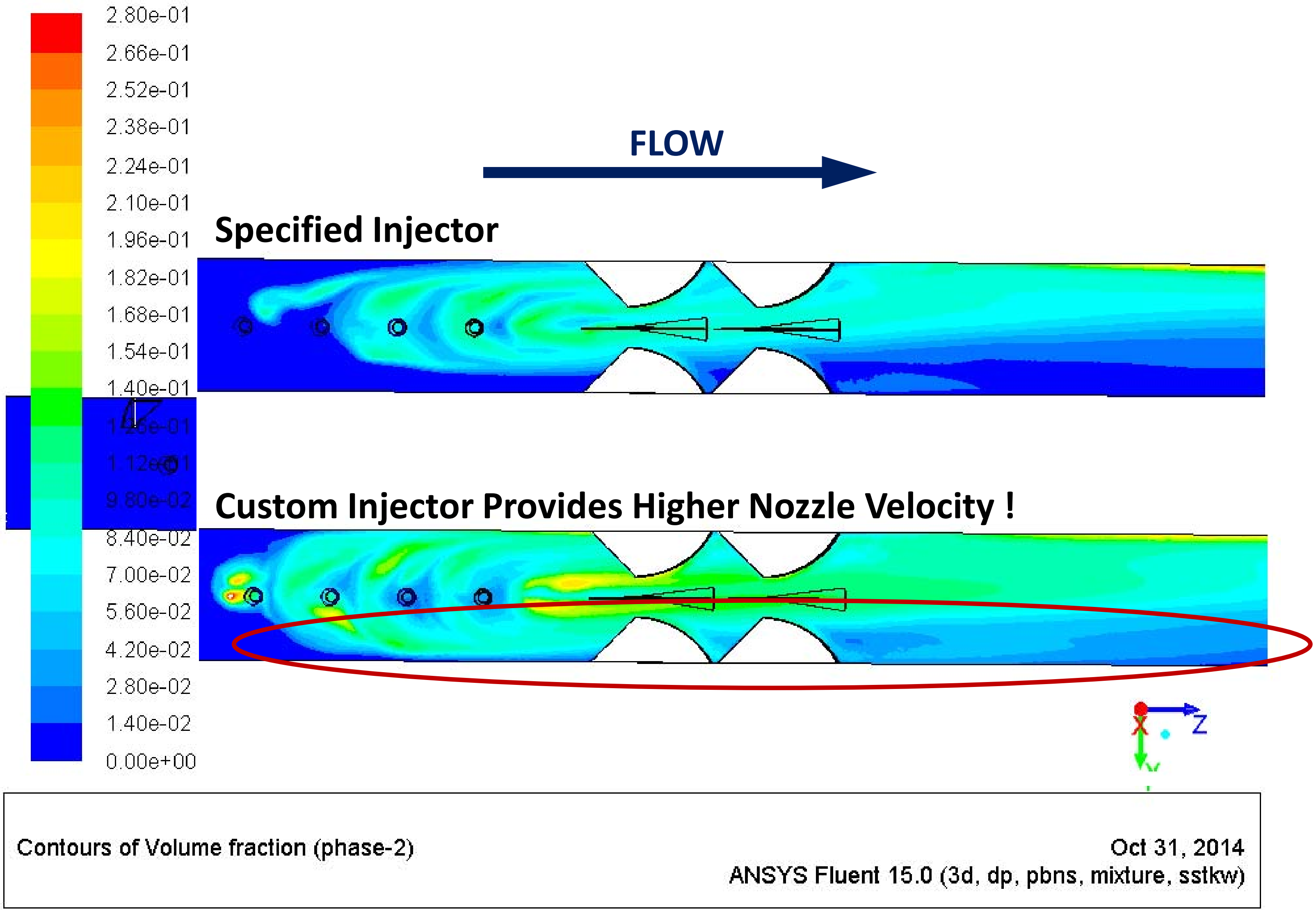


Mazzei Injector
Pipeline Flash Reactor Ozone Transfer Projections

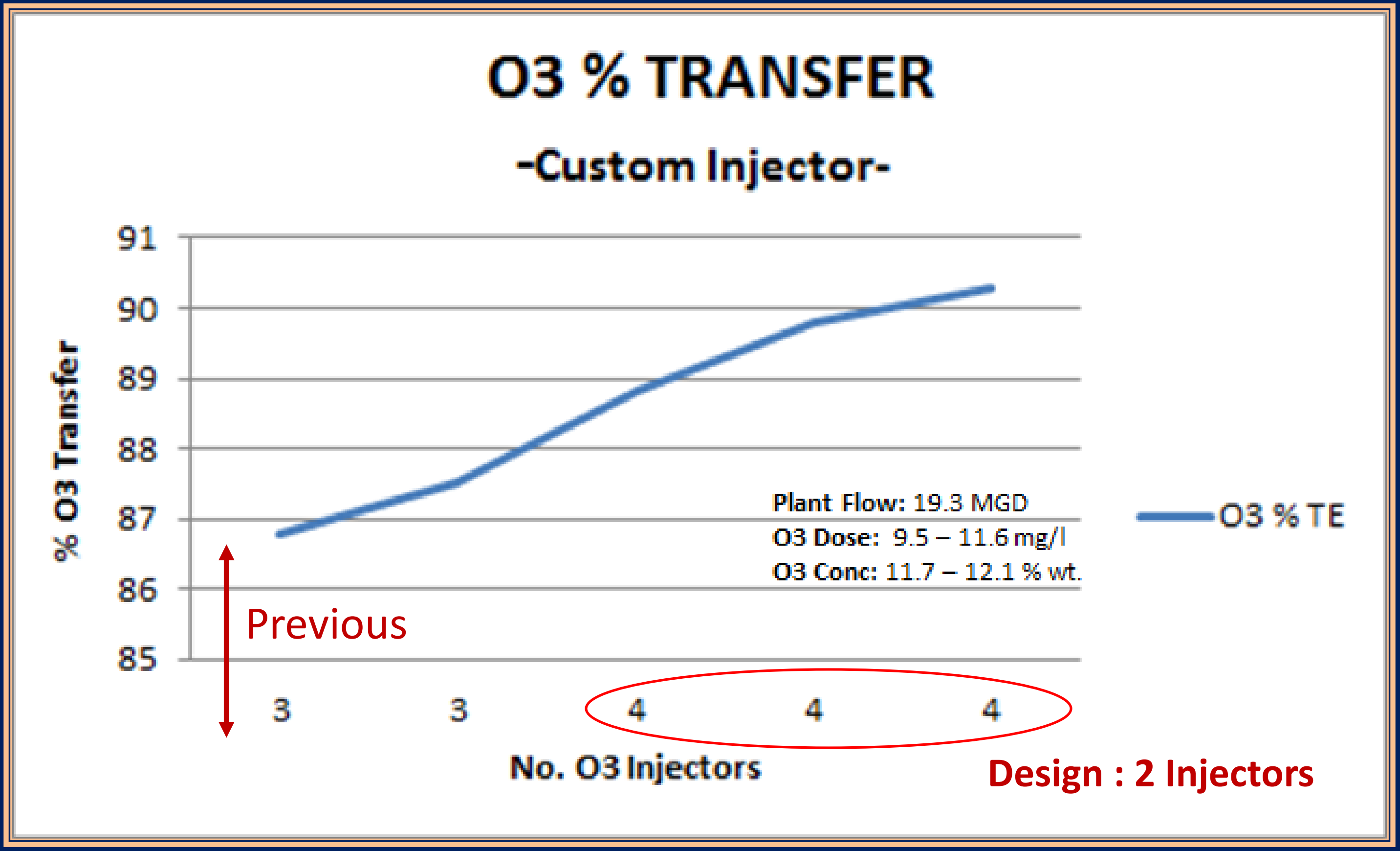
Prepared For:	Wharton Smith
Project:	OUC SW WTP: 26.6 MGD flow to 3 contact basins
Purpose for Ozonation:	H2S Oxidation
Date:	8-May-15

26.6 MGD	Gas contacting all of the water. Low pipeline hydrostratic water pressure								
Contacted Flow Volume GPM	Contactor Operating Pressure PSIG	Applied Ozone Dose mg/l	Ozone Gas Concentration wt %	Ozone Demand Ratio	Required Ozone Injection Rate lbs./hr	Required Ozone Gas Flow SCFM	Calculated Gas/Liquid Ratio Vg/Vl	Mass Transfer Efficiency, MTE %	Calculated Ozone Residual mg/l
18472	2	9.8	12	0.75	90.59	144.00	0.06	96.4	2.36
15.96 MGD (60%)	Gas contacting only 60% of the water. Low pipeline hydrostatic water pressure.								
Contacted Flow Volume GPM	Contactor Operating Pressure PSIG	Applied Ozone Dose mg/l	Ozone Gas Concentration wt%	Ozone Demand Ratio	Required Ozone Injection Rate #/hr	Required Ozone Gas Flow SCFM	Calculated Gas/Liquid Ratio Vg/Vl	Mass Transfer Efficiency, MTE %	Calculated Ozone Residual mg/l
11083	2	16.33	12	0.75	90.59	144.00	0.10	82.8	1.27

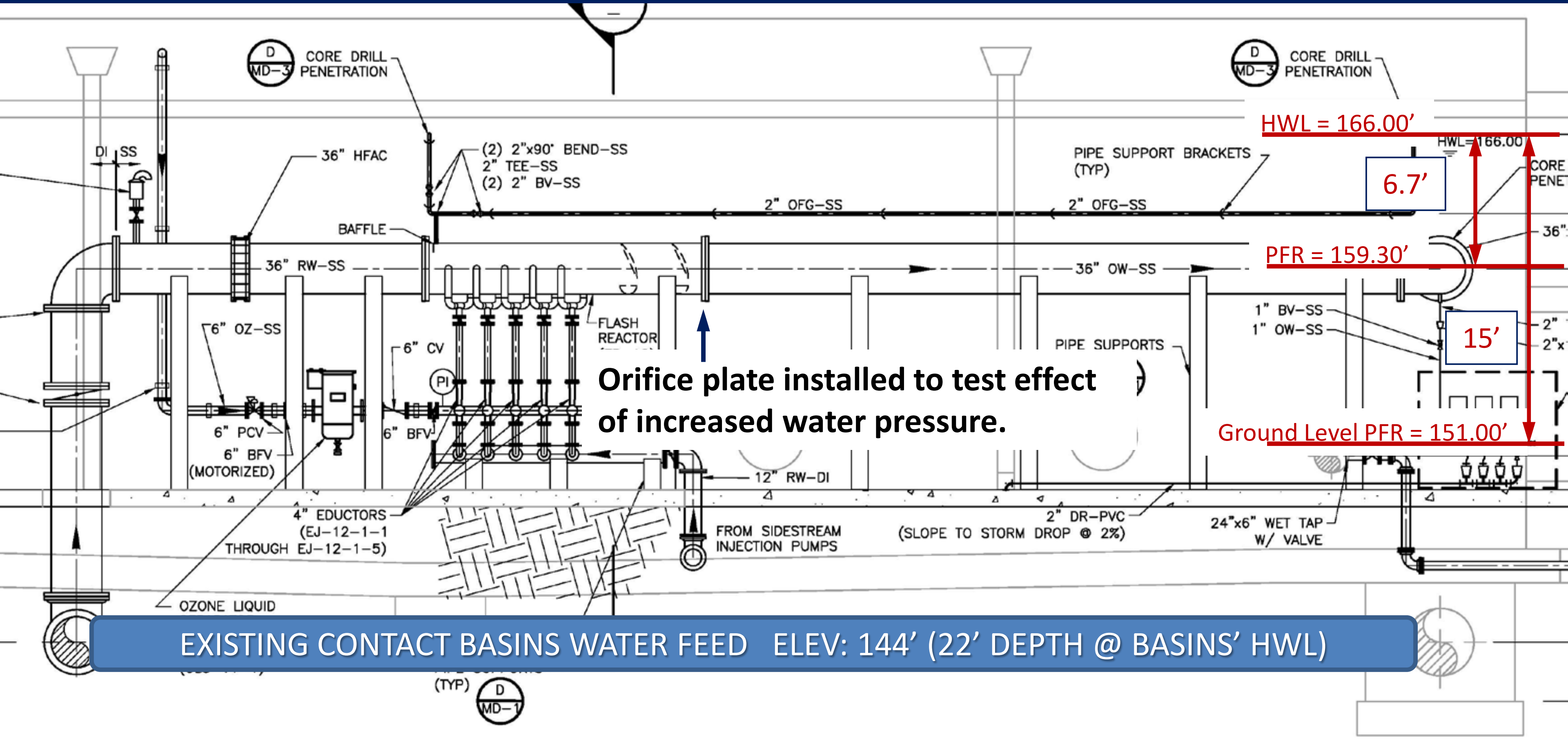
Specified vs Custom High Flow Injectors
26.6 MGD & 3 Gas Injectors



CUSTOM INJECTOR PERFORMANCE

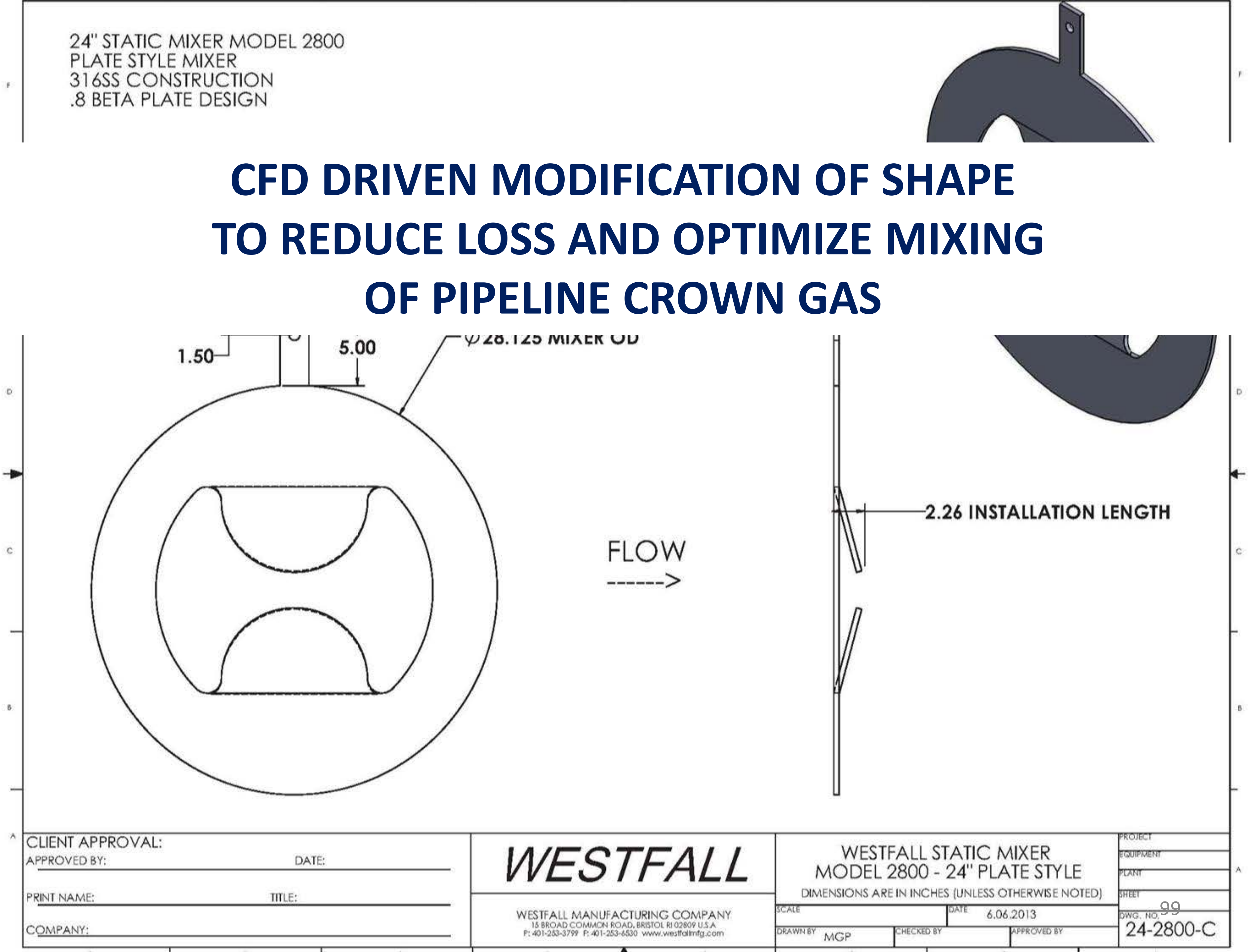


RE-LOCATE PIPELINE FLASH REACTOR ?



OUC SW WTP INJECTION SYSTEM LAYOUT

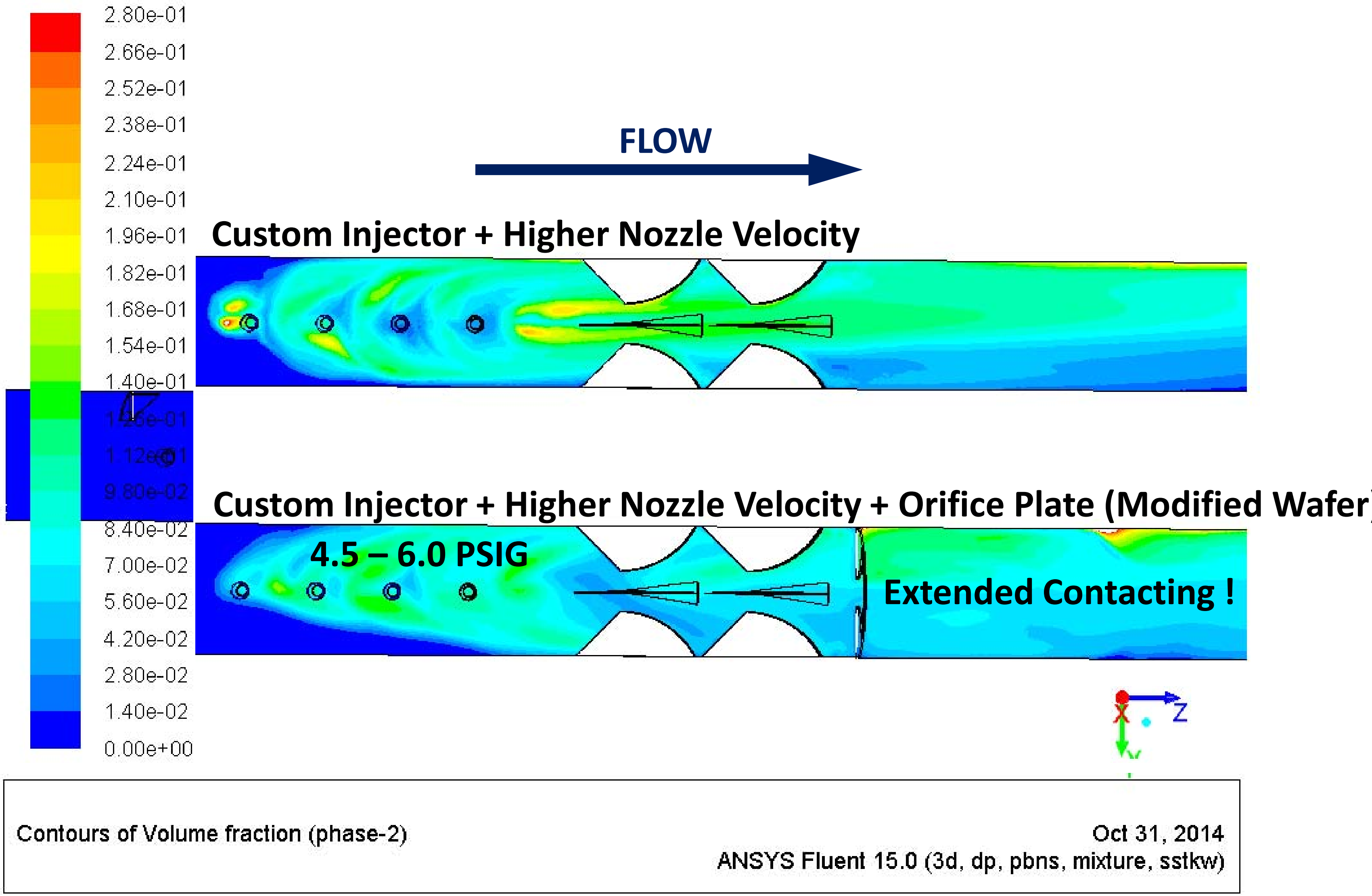
CFD DRIVEN MODIFICATION OF SHAPE TO REDUCE LOSS AND OPTIMIZE MIXING OF PIPELINE CROWN GAS



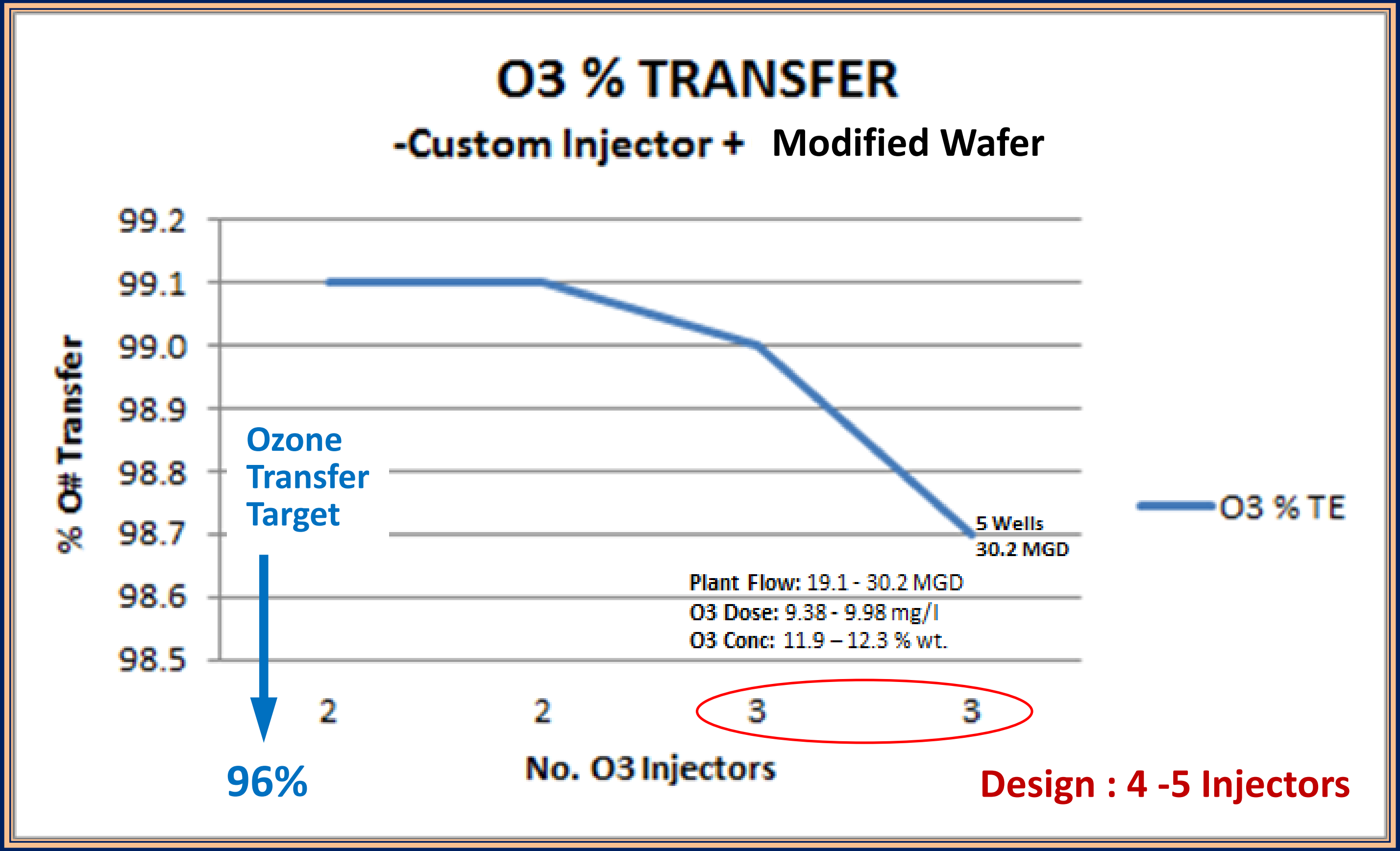

Orifice Plate
(Modified Wafer Mixer)
Pipeline Crown Gas

PIPELINE CFD COMPARISON

26.6 MGD & 3 Gas Injectors



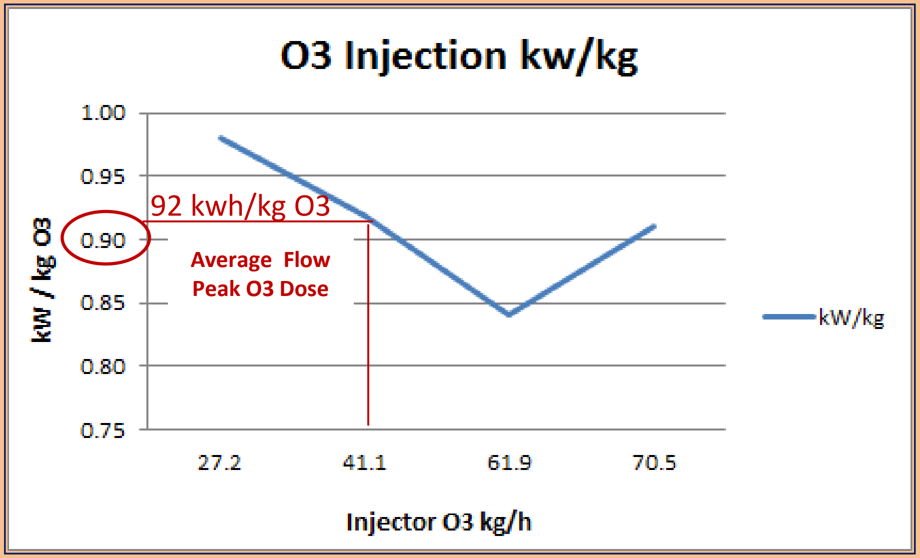
CUSTOM INJECTOR + ORIFICE PLATE



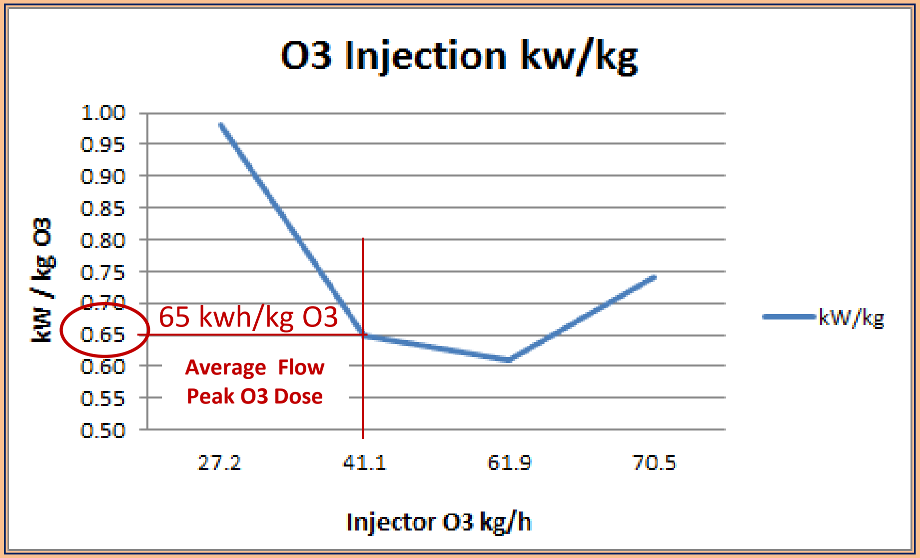
INJECTION SYSTEM IMPROVEMENT
-Energy Cost-

Energy cost savings of 27 kwh/kg of ozone applied !

Injection System Design



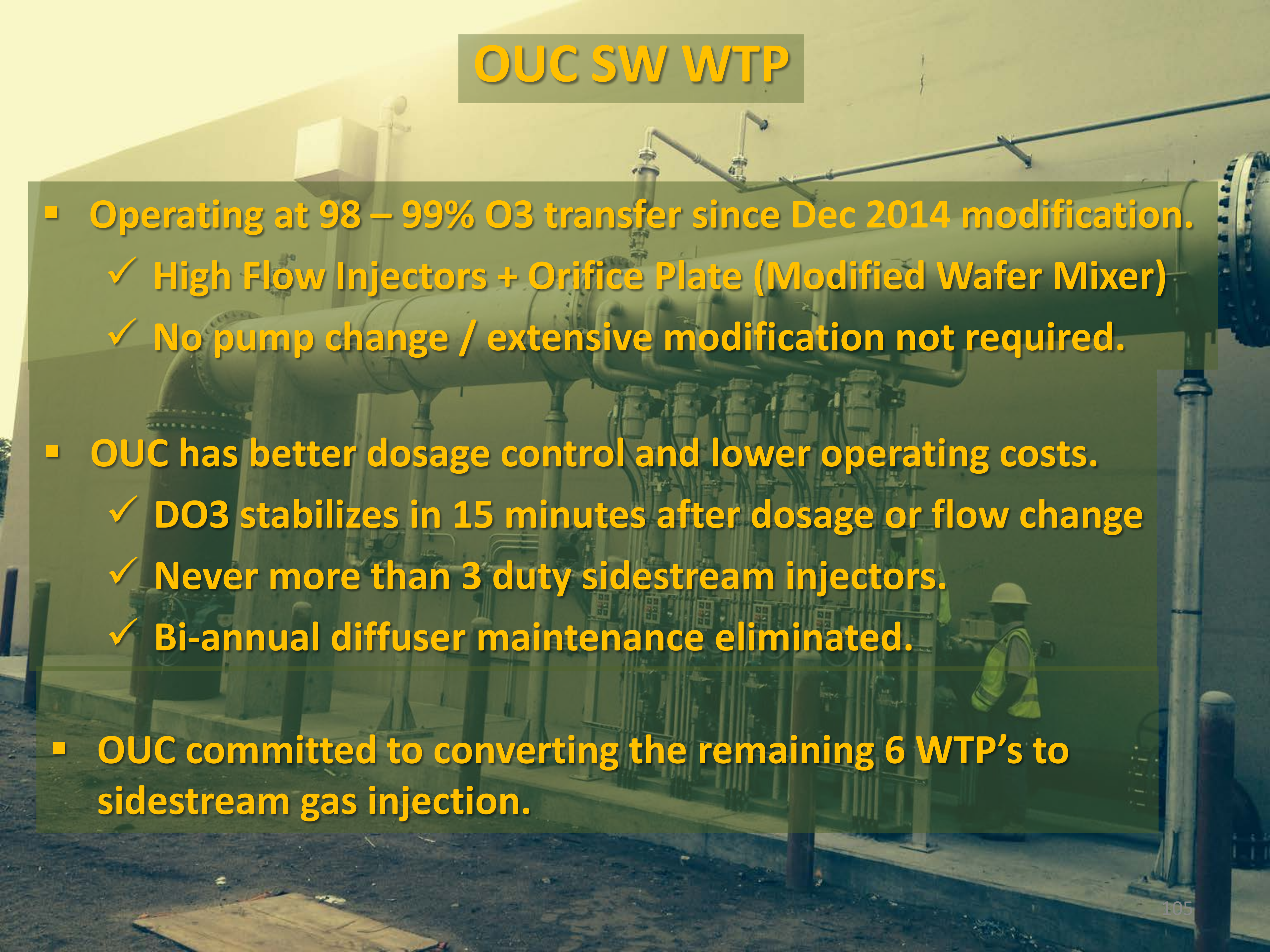
Injection System Improvement



ADDITIONAL SAVINGS

REDUCED LOX AND OZONE GENERATOR POWER

DUE TO OZONE TE OF 98 – 99 % !



OUC SW WTP

- Operating at 98 – 99% O_3 transfer since Dec 2014 modification.
  - ✓ High Flow Injectors + Orifice Plate (Modified Wafer Mixer)
  - ✓ No pump change / extensive modification not required.
- OUC has better dosage control and lower operating costs.
  - ✓ DO_3 stabilizes in 15 minutes after dosage or flow change
  - ✓ Never more than 3 duty sidestream injectors.
  - ✓ Bi-annual diffuser maintenance eliminated.
- OUC committed to converting the remaining 6 WTP's to sidestream gas injection.

SUMMARY

- Ozone was discovered in the mid-1800's.
- Ozone is generated on site using Oxygen and Electricity.
- Regulators promoted use of ozone disinfection after 1993 outbreak of Cryptosporidium.
- Ozone is dissolved into water using gas diffusion or Venturi gas injection.
- Ozone contactors are enclosed and pass ozone off gas through a ozone destruct module which converts O3 to O2 before gas discharge to atmosphere.

SUMMARY

- All ozone plants must have ambient air ozone gas monitors to prevent operator exposure to ozone gas.
- Venturi gas injection uses secondary gas mixing devices: Basin Nozzle Manifolds or Pipeline Flash Reactors.
- High ozone transfer efficiency requires water depth !

QUESTIONS ?

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