Model Based Development of a Pipeline Contactor for High Turndown and High Ozone Dose Applications

International Ozone Association – PAG 2019

Srikanth S. Pathapati Ph.D., Angelo L. Mazzei

Mazzei Injector Company LLC, Bakersfield, California, USA

Mixing and mass transfer – equally important?

Mass Transfer Efficiency (MTE) is the main index for evaluating efficiency of contacting system

- Example: Sidestream contacting
  - Mainline applied ozone dose = 10 mg/L
  - Sidestream % = 5%
  - If only 50% of the main line is being contacted, **effective localized dose = 20 mg/L!**

Mixing is crucial to ensure all the mass is transferred efficiently

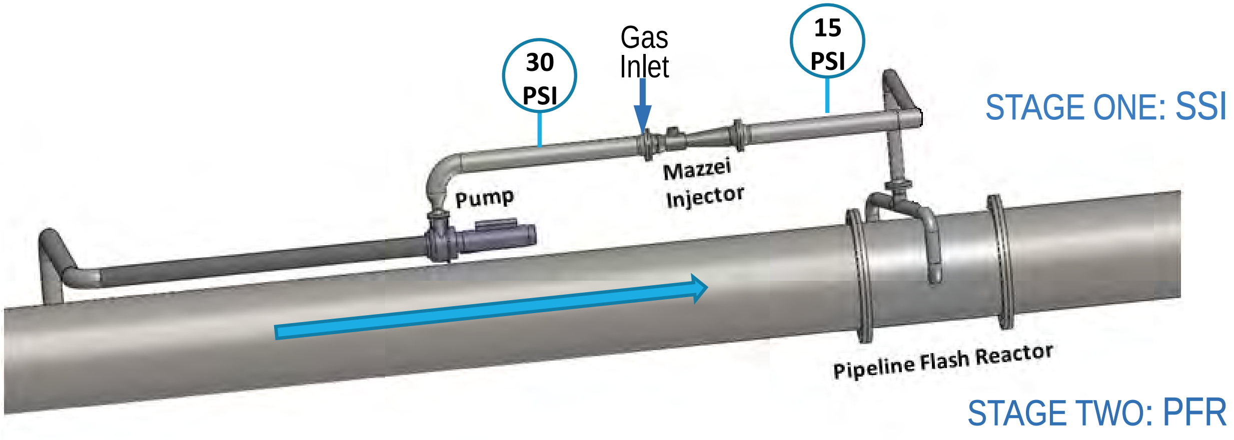
Poor mixing results in:

- Missed MTE targets
- **Inefficient and incomplete treatment**

Background

SIDESTREAM GAS INJECTION

Pipeline Flash Reactor



A Two-Stage Transfer of Gas to Solution

Challenges to Mixing and Mass Transfer

1. Infrastructure

- Particularly challenging in retrofits
  - "Plug-in" to existing layouts – less control over physical processes
- Limited footprint

2. Ozone doses

- Ozone generators produce up to 20 percent ozone today
- Water reuse – high ozone demand

1 and 2 can be investigated and addressed by model based design and engineering

Challenges to Mixing and Mass Transfer (continued)

3. Unknown or incomplete water chemistry

- Guessing ozone demand!

4. Designed versus actual pressure

- Sensitivity to available water column pressure – 1 psi makes a difference

Objectives

1. Test the limits of current pipeline contacting method for

1. High ozone doses (>10mg/l)
2. High turndown (>5:1)

2. Achieving mass transfer and mixing targets while maintaining stable O3 residual

1. Ozone Contacting System Design
2. Sampler Design

High Dose Ozone Applications

Water Reuse

- North America
  - Severe drought in Southwest United States
  - High profile, large scale reuse projects
    - San Diego Pure Water
    - Monterey Pure Water
- Europe
  - EU Blueprint to Safeguard Europe's Water Resources
- Asia
  - City of Chennai runs out of water
- Africa
  - Day Zero for Cape Town

Odor Control

- Ozone to H_2S stoichiometry is 5:1
  - Orlando Utilities Commission, Florida – second largest and Florida and 14th largest in USA

Typical ozone doses are greater than 10 mg/L

High Turndown in Contacting Systems

One system to treat flows with main line velocities ranging from 1 ft/s to 7 ft/s

- Accommodate transitional to fully turbulent flow
  - Most static elements are designed for a narrow operational range

Advantage of Sidestream Venturi Injection

- Typical ranges 4:1
- New ranges >4:1
  - as high as 13:1
    - Hansen WTP, Kansas, USA: 10 MGD TO 127.5 MGD in 84 inch pipeline

Design Challenge: ***Extend Range of Operation for Pipe Velocities Without Significant Pressure Loss***

mazzei®

CASE STUDY: HIGH OZONE DOSAGE CHALLENGE

ORLANDO UTILITIES COMMISSION: SOUTHWEST WTP

Background

Orlando Utilities Commission

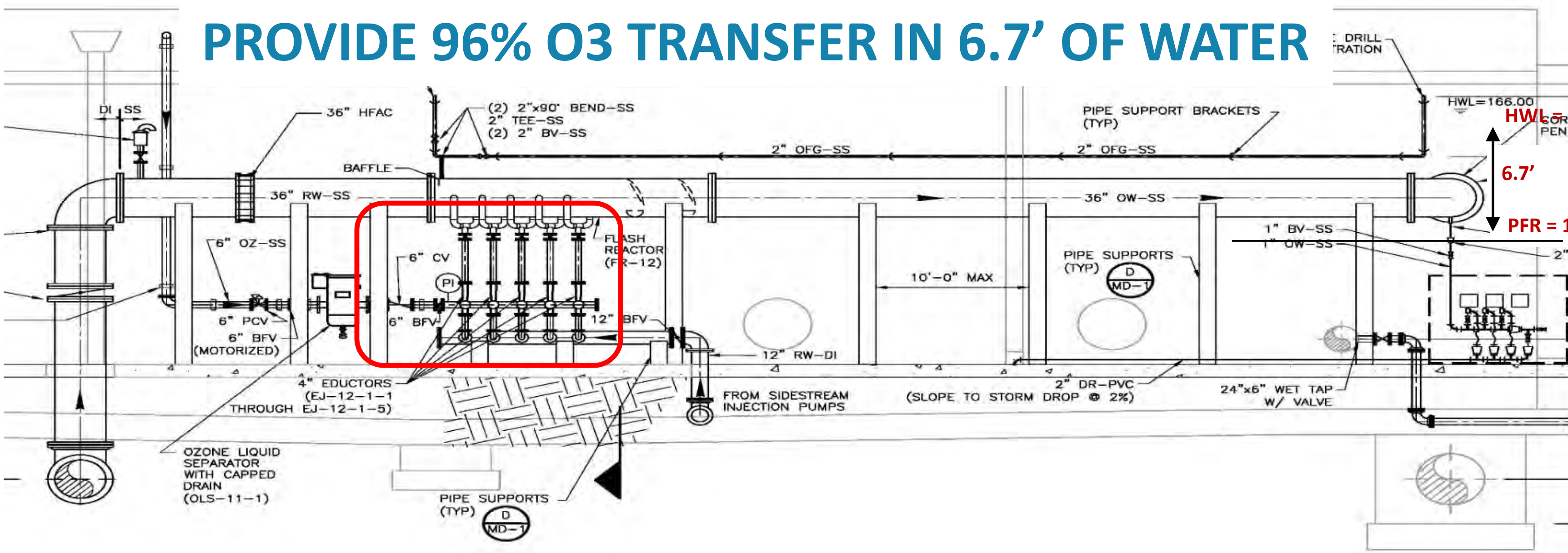
- Established in Orlando, Florida in 1923 by the Florida Legislature.
- Operates seven (7) water treatment plants @ > 200 MGD.
- Has been using ozone since the early 1990’s
- Applied ozone dosage ranges from 8.0 – 14.8 mg/l
- Using gas diffusion at all plants; SW WTP changed to sidestream injection in 2014.

mazzei®

SW WTP Injection Retrofit [45 MGD @ 8.5 – 9.0 mg/l O3]

GAS INJECTION CHALLENGE

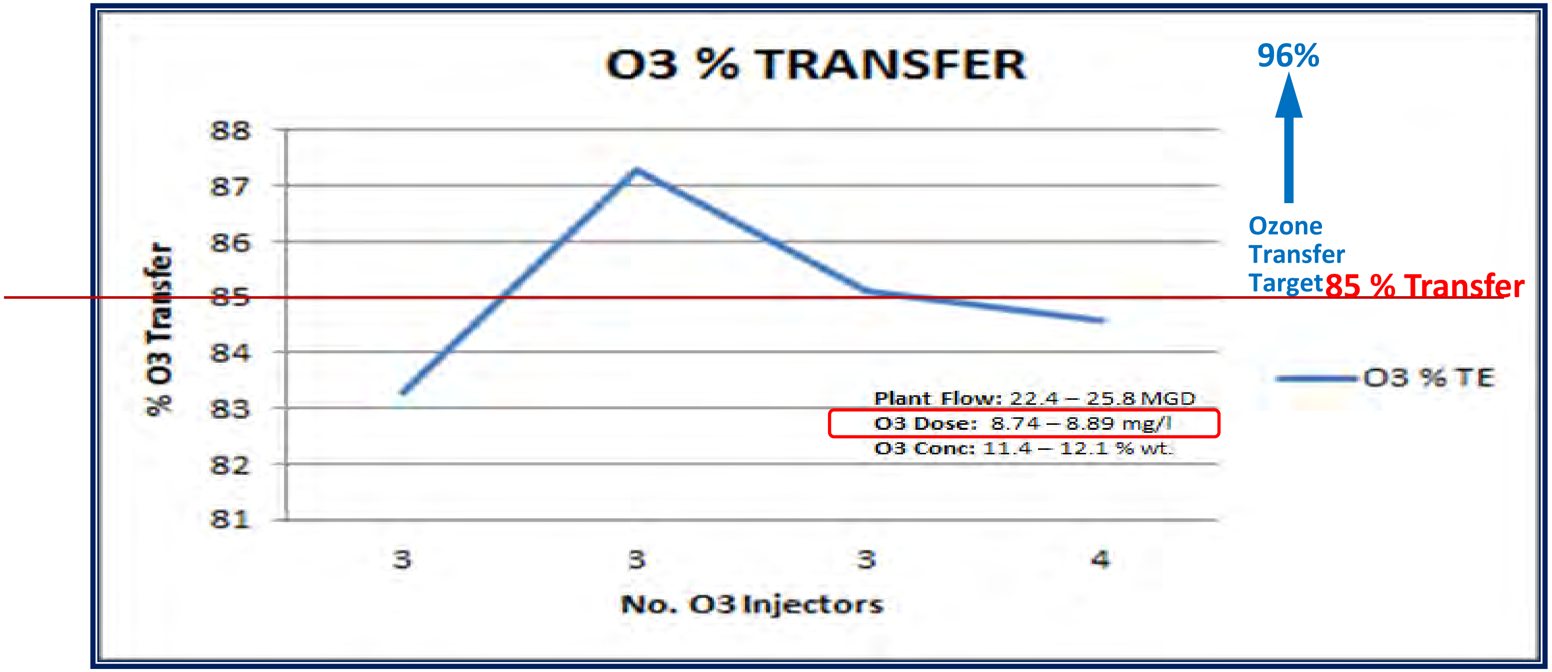
PROVIDE 96% O3 TRANSFER IN 6.7’ OF WATER



EXISTING DIFFUSION BASINS WATER FEED ELEV: 144’ (22’ DEPTH @ BASINS’ HWL)

mazzei®

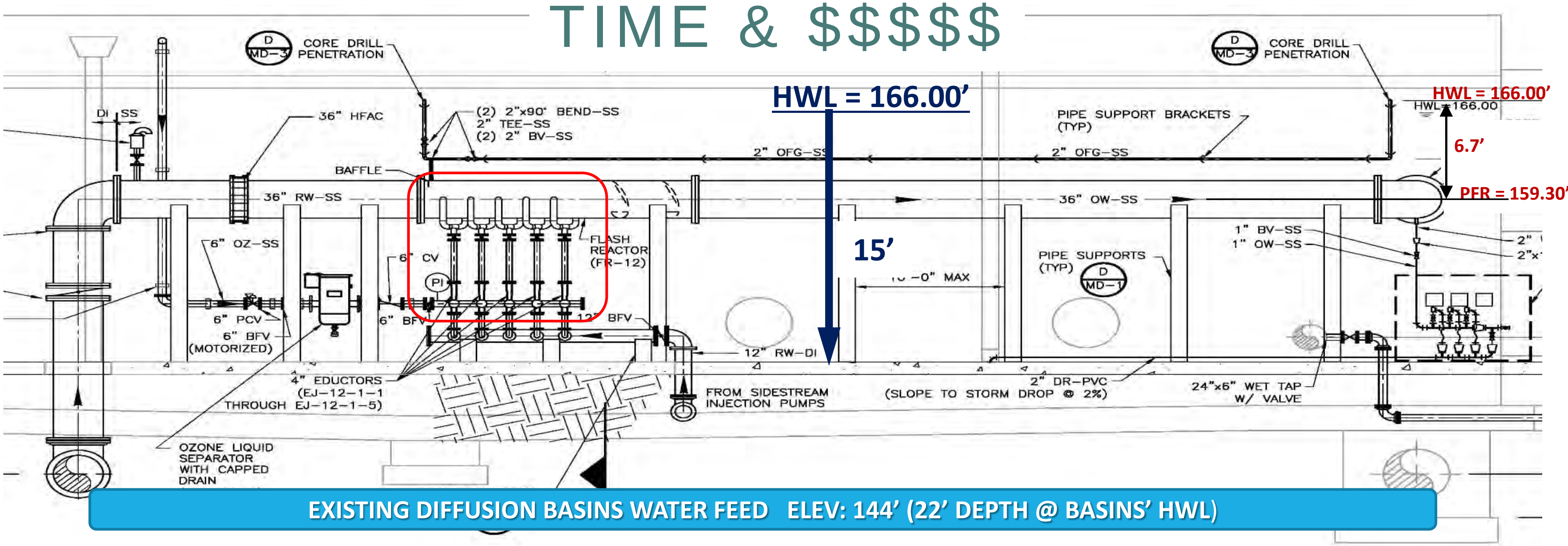
OUC SW WTP Ozone Transfer Performance Testing



Possible Solution #1

DROP ELEVATION OF PIPELINE WITH PFR ?

TIME & $$$$$

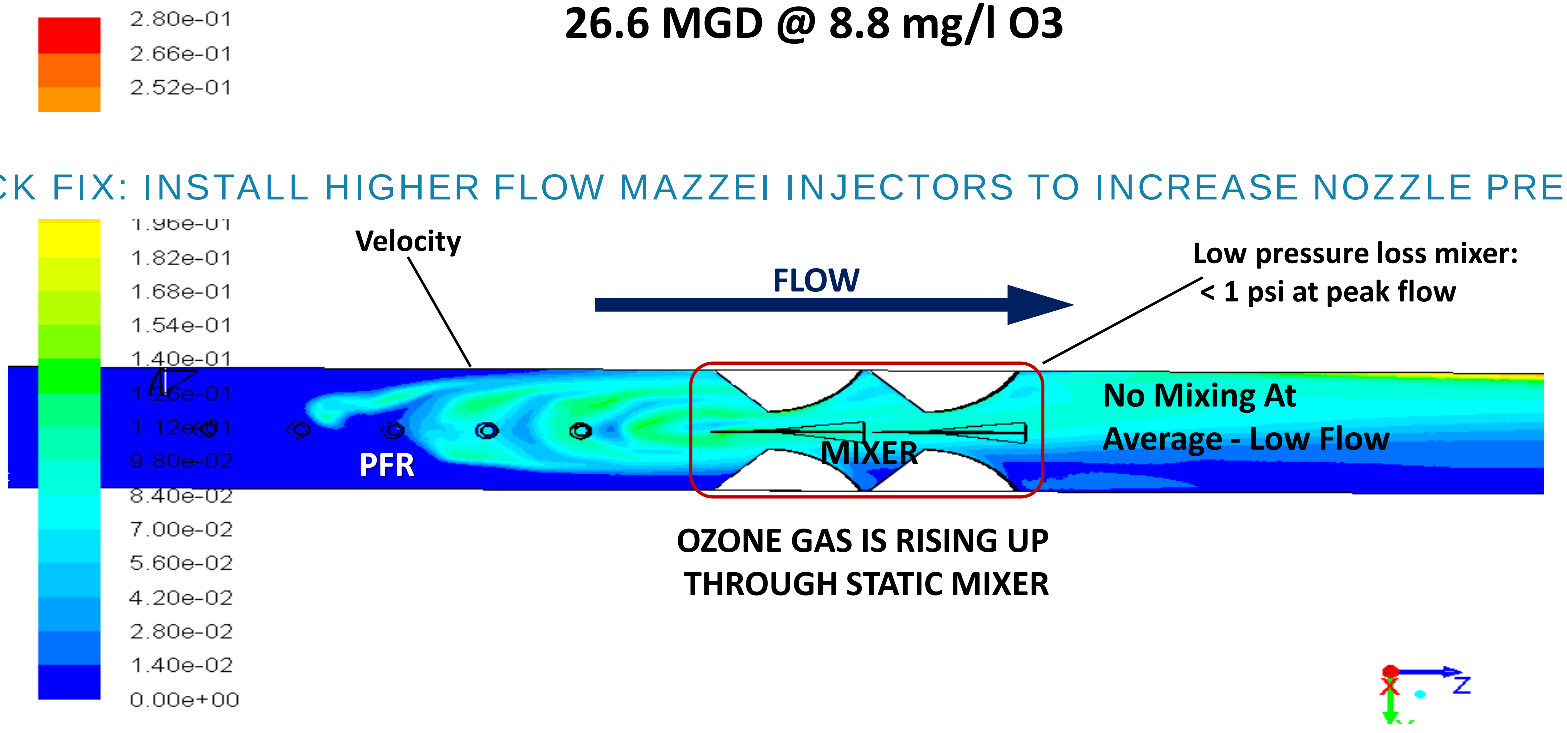


mazzei®

CFD - Possible Solution #2

SPECIFIED INJECTOR, PFR AND MIXER
26.6 MGD @ 8.8 mg/l O3

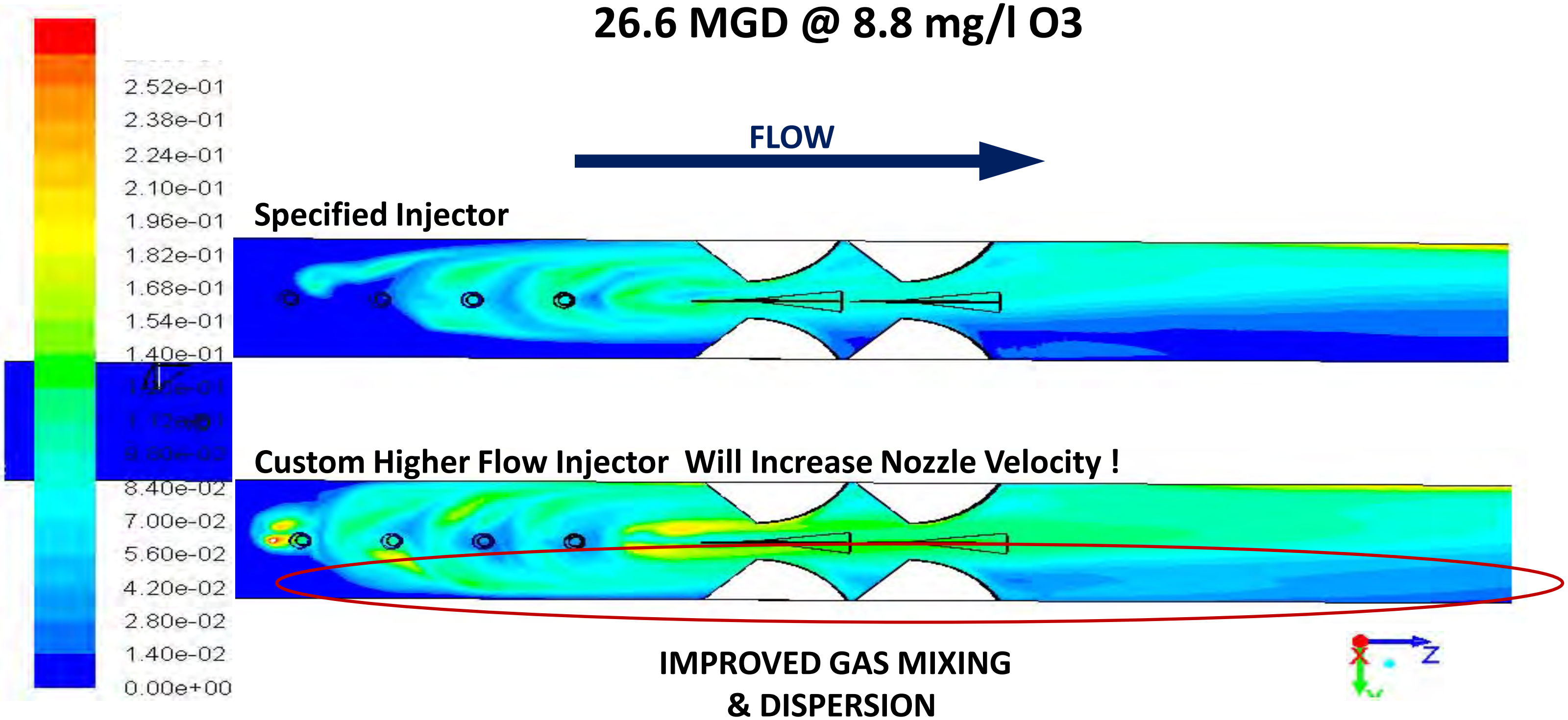
QUICK FIX: INSTALL HIGHER FLOW MAZZEI INJECTORS TO INCREASE NOZZLE PRESSURE



CFD Possible Solution #2

CFD MODEL OF GAS MIXING AT HIGHER NOZZLE PRESSURE

26.6 MGD @ 8.8 mg/l O3

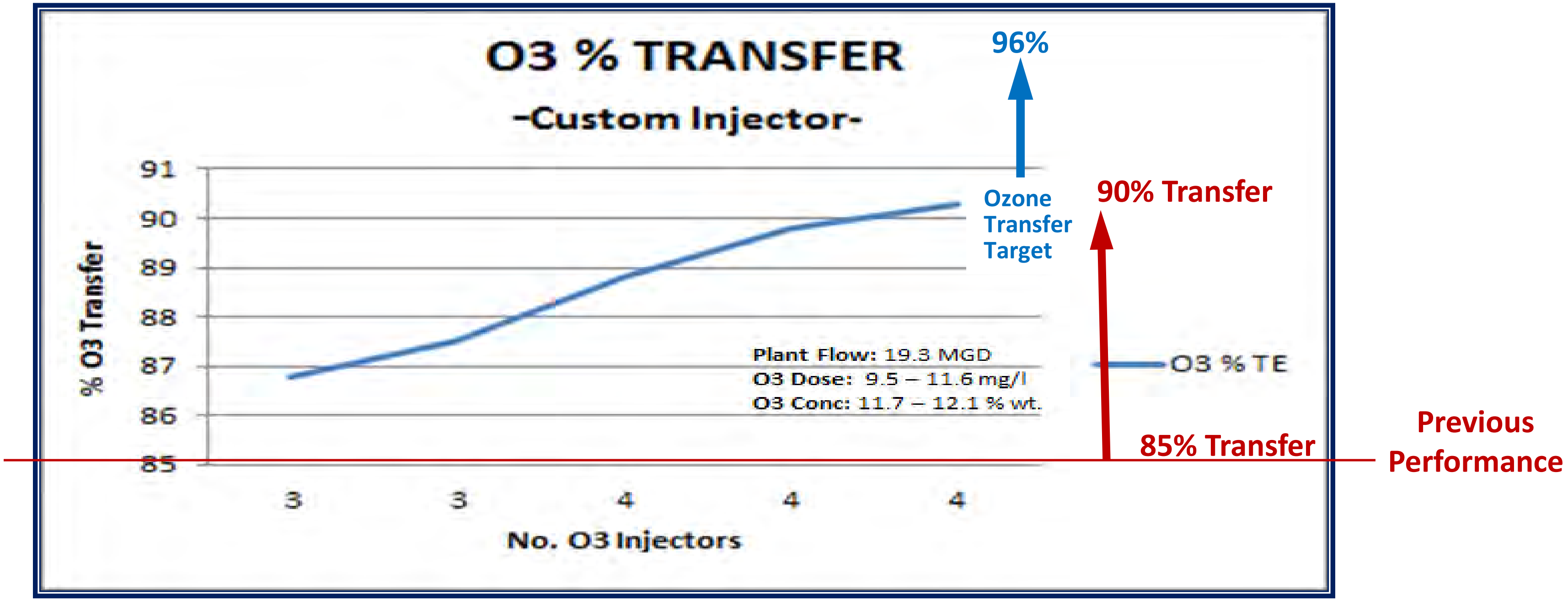


mazzei®

Solution #2 – Ozone Transfer Performance Testing

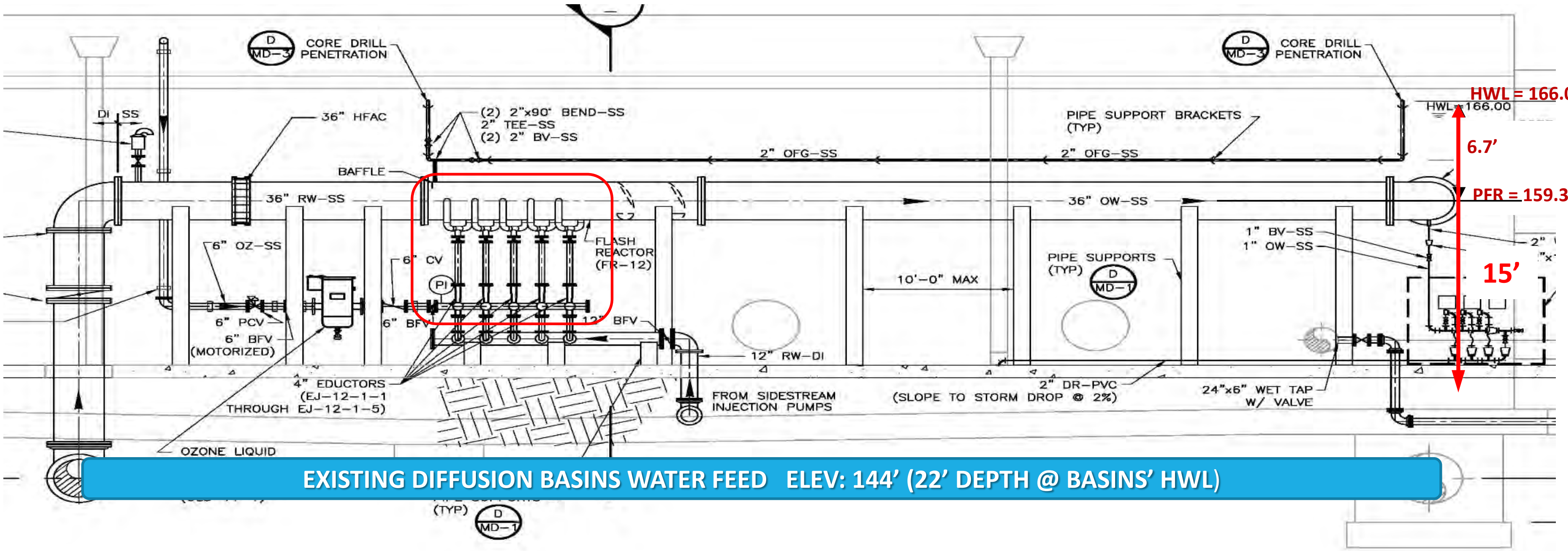
CUSTOM HIGH FLOW INJECTOR INCREASES NOZZLE VELOCITY

26.6 MGD @ 8.8 mg/l O3

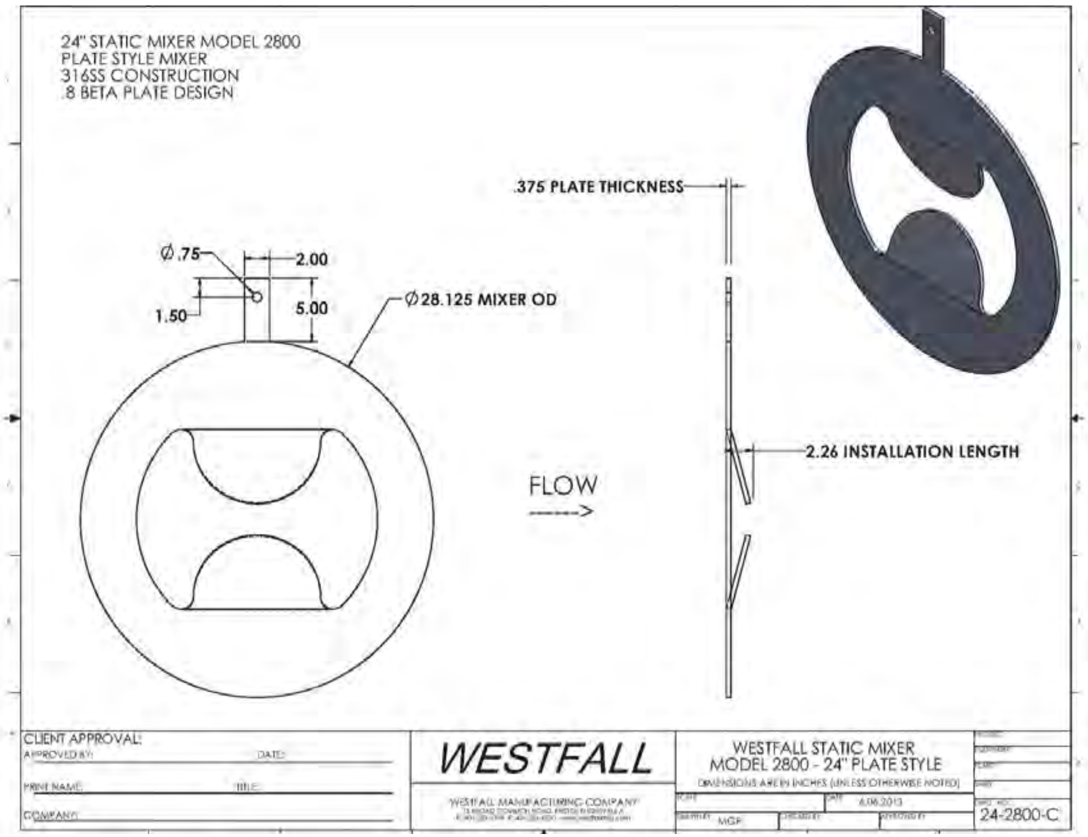


Possible Solution #1?!

DROP ELEVATION OF PIPELINE WITH PFR !



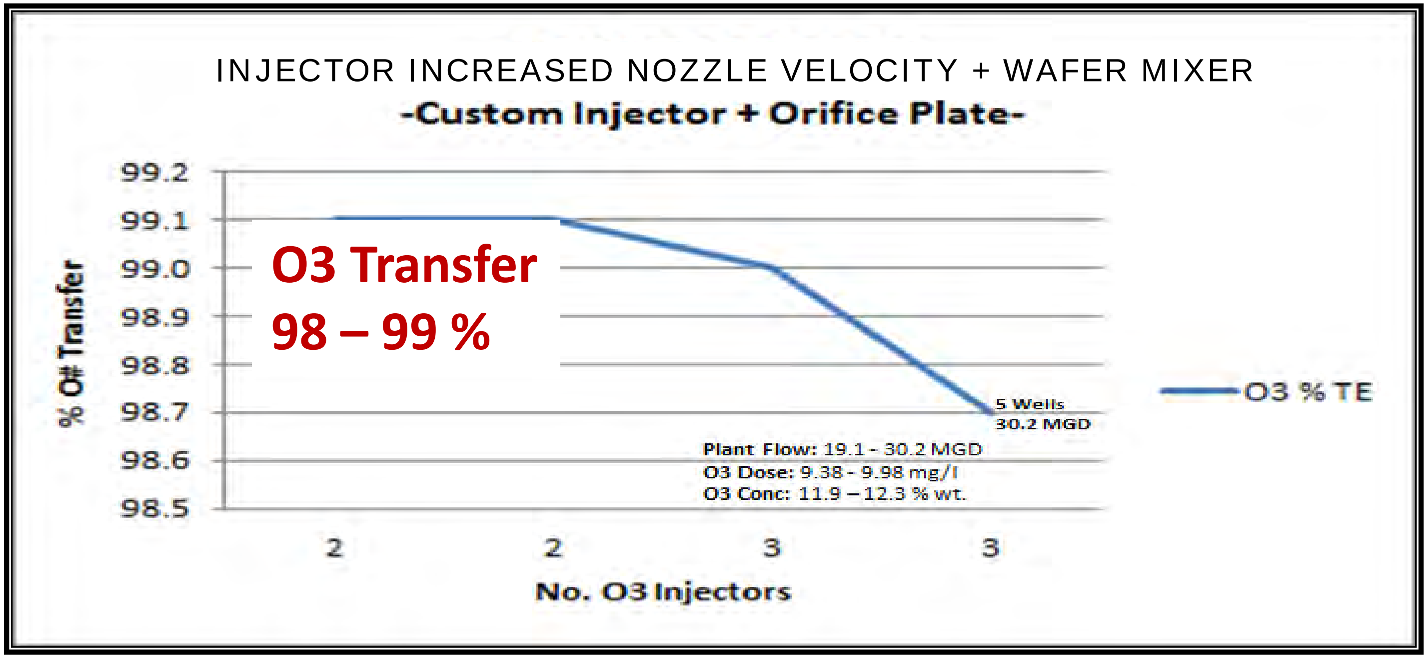
Possible Solution #3? Westfall Wafer Mixer




Westfall Wafer Mixer
Increase 1-3 psig to 4 – 6 psig
Pipeline Crown Gas Remix

Solution #3 – Ozone Transfer Performance Testing

ADDITION OF WAFER MIXER DOWNSTREAM OF PFR



Summary – High Dose Case Study

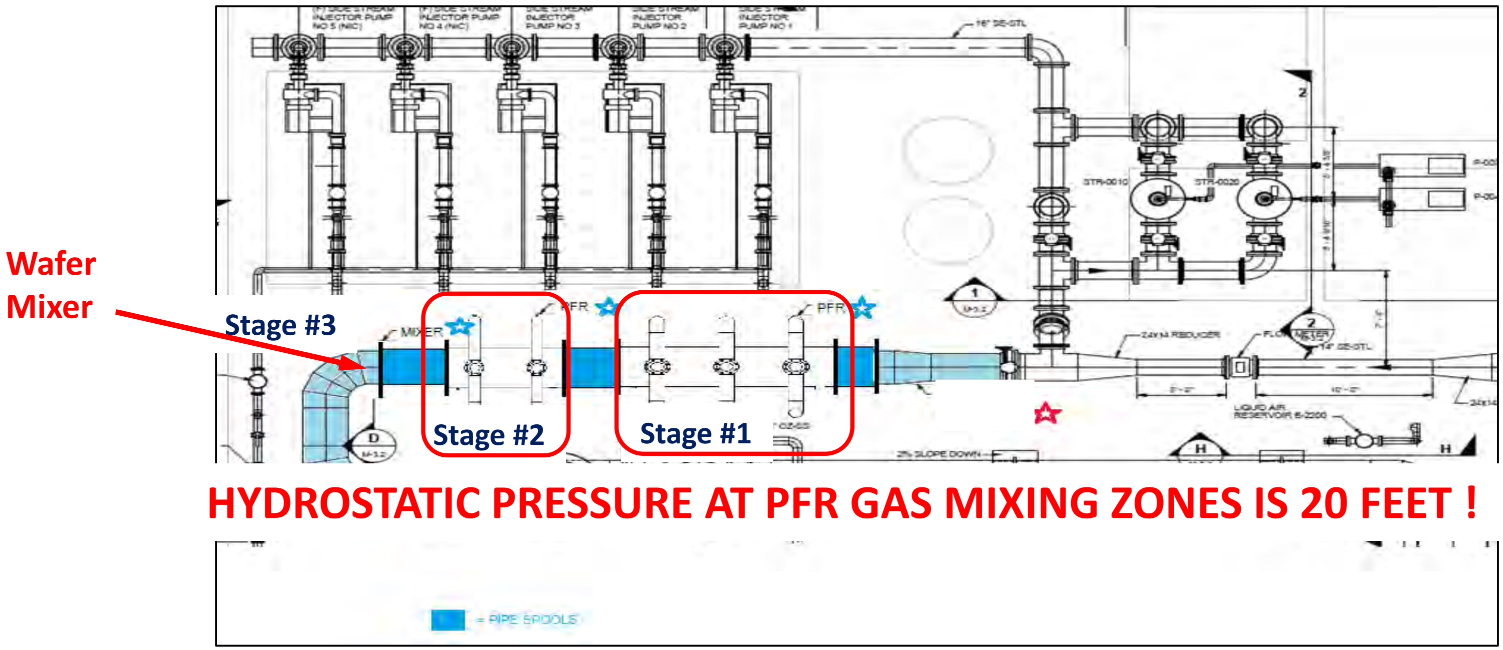
- **A higher PFR nozzle pressure is required for high ozone dosage applications.**
- **High flow, low loss mixers have reduced gas mixing at plant turn down.**
- **A minimum pipeline pressure of 5 – 6 psig, 12 – 13 feet, needed for ozone transfer.**
- **Uncertain what pipeline crown gas remixing by wafer contributed to O3 transfer.**

In a pipeline with adequate hydrostatic pressure for gas transfer, the pressure loss of the wafer mixer and resulting increased plant pumping costs makes it hard to justify it's use.

Water Reuse installation

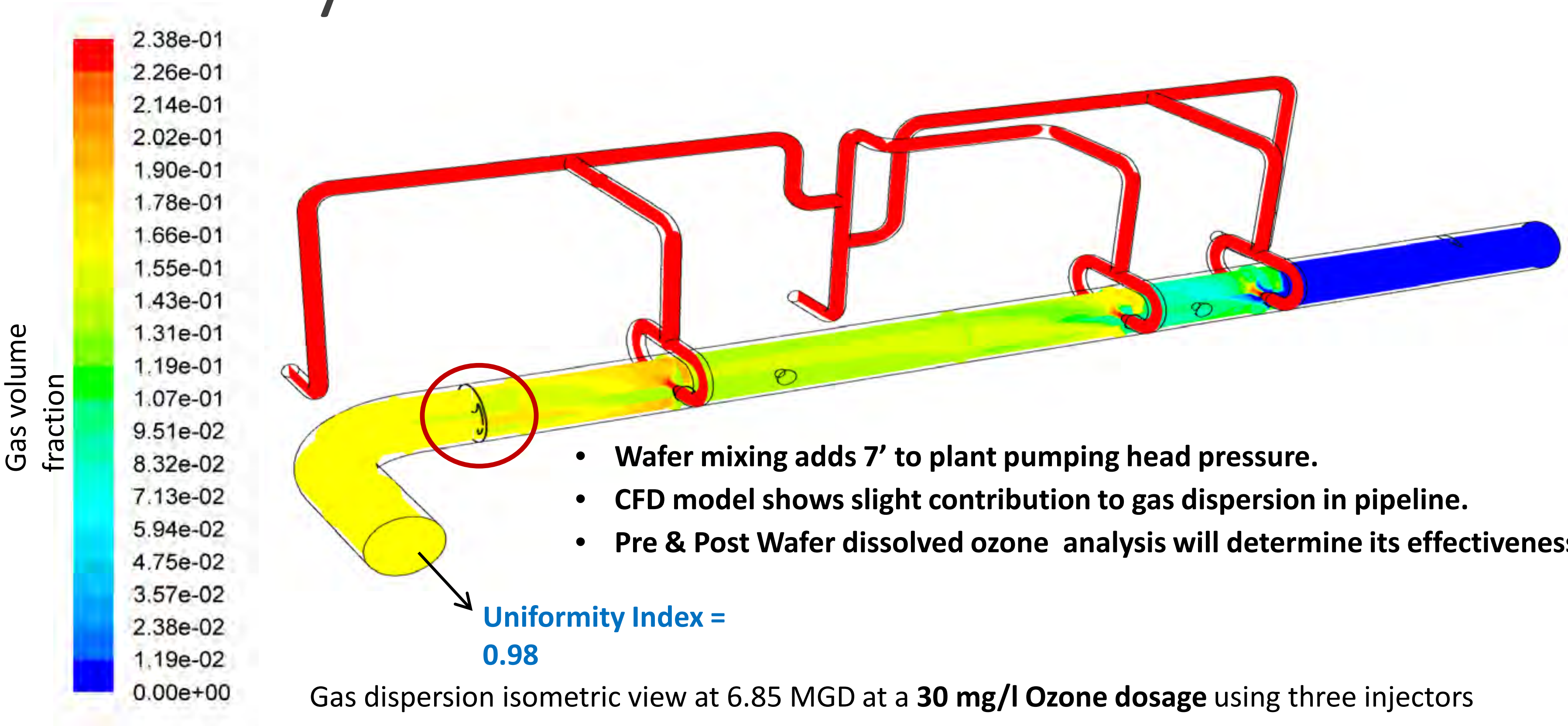
PURE WATER MONTEREY

30 mg/l OZONE DISSOLUTION CONTACTOR



HYDROSTATIC PRESSURE AT PFR GAS MIXING ZONES IS 20 FEET !

CFD design – High Dose Case Study



- **Wafer mixing adds 7' to plant pumping head pressure.**
- **CFD model shows slight contribution to gas dispersion in pipeline.**
- **Pre & Post Wafer dissolved ozone analysis will determine its effectiveness.**

Gas dispersion isometric view at 6.85 MGD at a **30 mg/l Ozone dosage** using three injectors

MODEL BASED DESIGN CHALLENGE:

TREAT HIGH DOSE, HIGH TURNDOWN IN PIPELINE WITH MINIMAL PRESSURE LOSS

Design Philosophy

Mechanisms of gas-liquid mixing can be broadly classified as:

- Bubble shear/breakup
  - Rapid renewal of gas-liquid interface
- Blending
- Folding (at low Re)

Driving Variables for Design:

- Pipeline velocity profiles
- Ozone dose and concentration
- Gas:liquid ratio (both sidestream and mainline)
- Sidestream flow ratio
- Water quality (instantaneous and long-term ozone demand)
- Mainline pressure

Mazzei

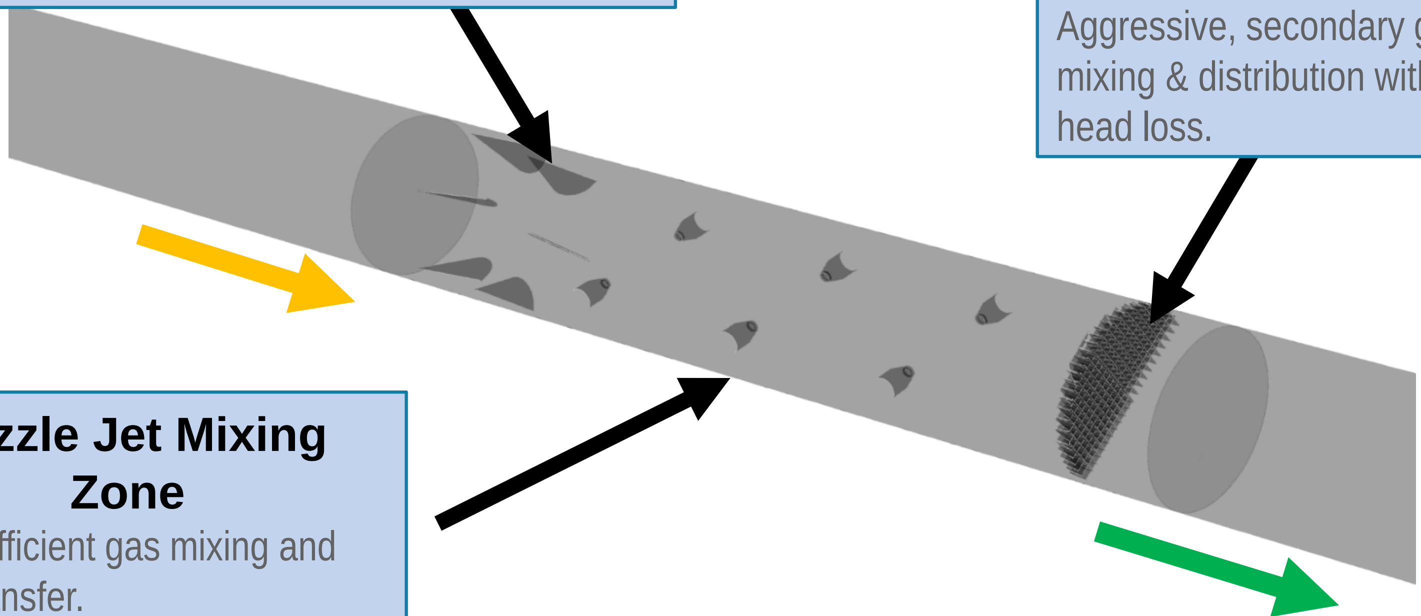
How It Works

Flow Conditioning Vanes

- Improved turndown capability at low velocities
- Provides turbulent mixing at low flows
- Uniform velocity profiles

Angular Mixing Grid

Aggressive, secondary gas mixing & distribution with low head loss.



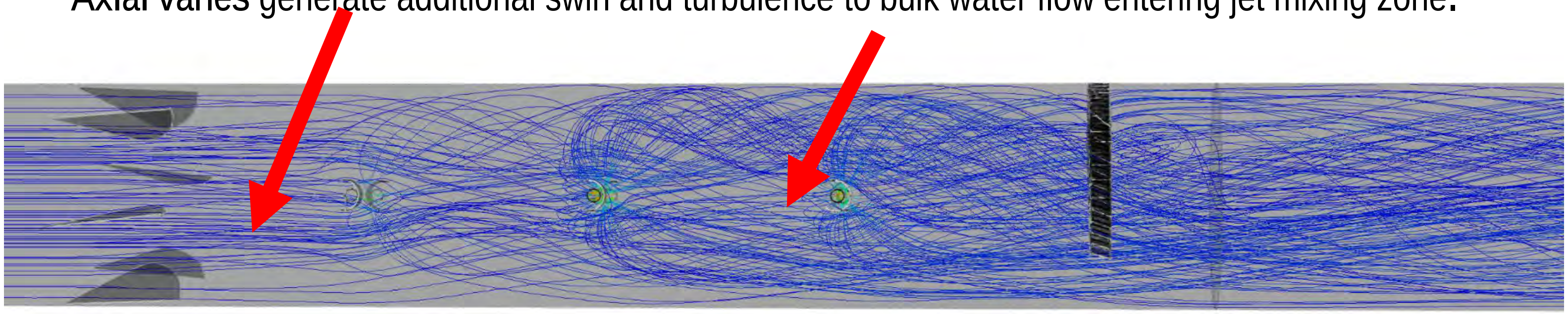
Nozzle Jet Mixing Zone

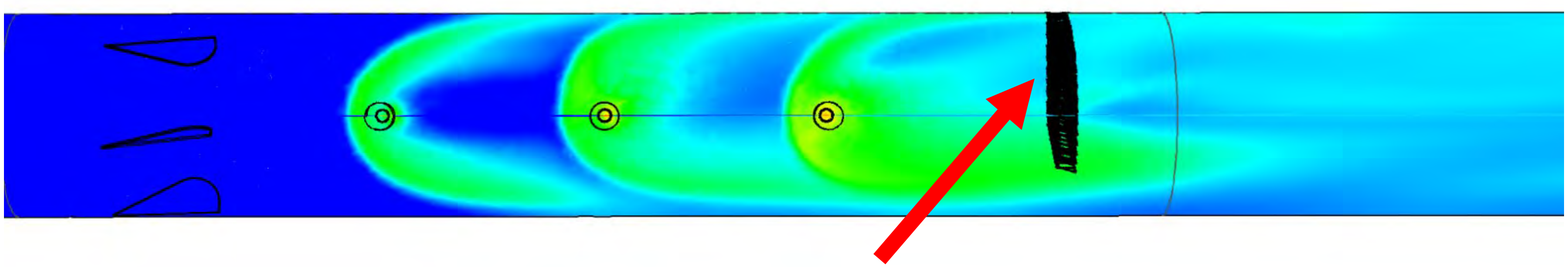
Rapid, efficient gas mixing and mass transfer.

RESULTS: Increased Mixing Uniformity &
Rapid, Reliable Mass Transfer – *US Patent granted in 2018*

Folding, Blending and Mixing *WITHOUT* Obstructing

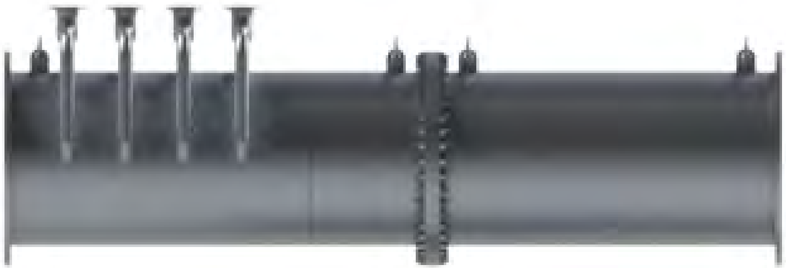
Axial vanes generate additional swirl and turbulence to bulk water flow entering jet mixing zone.





Grid pushes crowned gas back down into flow, maximizing contacting and mass transfer

PFR+ vs. PFR & STATIC MIXER
54" Diameter



- + Smaller Footprint than PFR & Static Mixer
- + Improved, Targeted Mixing
- + Exceptional Turn Down
- + Minimal Pressure Loss at Peak Flow (<0.25 psi at 8 ft/s)
- + Optimizes High Dose O3 Transfer

mazzei®

Conclusions

1. CFD Modeling used to extend range of pipeline contacting system for

- High ozone dose and high turndown

2. Model results predict excellent mixing and mass transfer with pressure loss less than 0.25 psi

Thank you! Questions?