COMPUTATIONAL FLOW MODEL OF WESTFALL'S 48” 2800 MIXER TO BE INSTALLED IN THE HYDROGEN SULFIDE REMOVAL FACILITY IN LITHIA, FLORIDA FOR TAMPA BAY WATER

Report 412506-1R1

By

Kimbal A. Hall, PE

Submitted to:

WESTFALL MANUFACTURING COMPANY

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ALDEN RESEARCH LABORATORY, INC.

30 Shrewsbury Street

Holden, MA 01520

INTRODUCTION

Alden Research Laboratory Inc. (Alden) was contracted by Westfall Manufacturing Inc. (Westfall) to evaluate the performance of a 48” 2800 mixer that is to be installed at the Hydrogen Sulfide Removal Facility (HRSF) in the City of Lithia, Florida for Tampa Bay Water. The objective of this mixer is to achieve a low coefficient of variation (CoV) of the injected fluid (sodium hypochlorite in this example) within a short distance downstream, while staying below the maximum pressure loss requirement. This report discusses the mixing downstream of the 2800 mixer in a few different mixer and injection orientations while installed in the actual Lithia HRSF piping layout at the maximum expected flow rate.

COMPUTATIONAL MODEL DESCRIPTION

The model geometry was developed using the commercially available three-dimensional CAD and mesh generation software, GAMBIT V2.4.6. The computational domain generated for the model consisted of 1.5 million cells.

Numerical simulations were performed using the CFD software package FLUENT 13.1, a state-of-the-art, finite volume-based fluid flow simulation package including program modules for boundary condition specification, problem setup, and solution phases of a flow analysis. Advanced turbulence modeling techniques, improved solution convergence rates and special techniques for simulating species transport makes FLUENT particularly well suited for this study.

Alden used FLUENT to calculate the full-scale, three-dimensional, incompressible, turbulent flow through the pipe and flow conditioner. A two-equation realizable k-ε model was used to simulate the turbulence. Detailed descriptions of the physical models employed in each of the Fluent modules are available from Ansys/Fluent, the developer of Fluent V13.1.

MODEL BOUNDARY CONDITIONS

The piping layout for the sodium hypochlorite injection section of the Lithia HSRF was modeled at full scale from 40-ft upstream of the bypass piping split, through the primary 48” static mixer (with the 36” line bypass valve closed), to a point 40-ft downstream of the bypass junction (Figure 1). The no-slip condition was applied to all pipe walls, with wall roughness set to 0.00015-ft, which is typical for steel pipe.

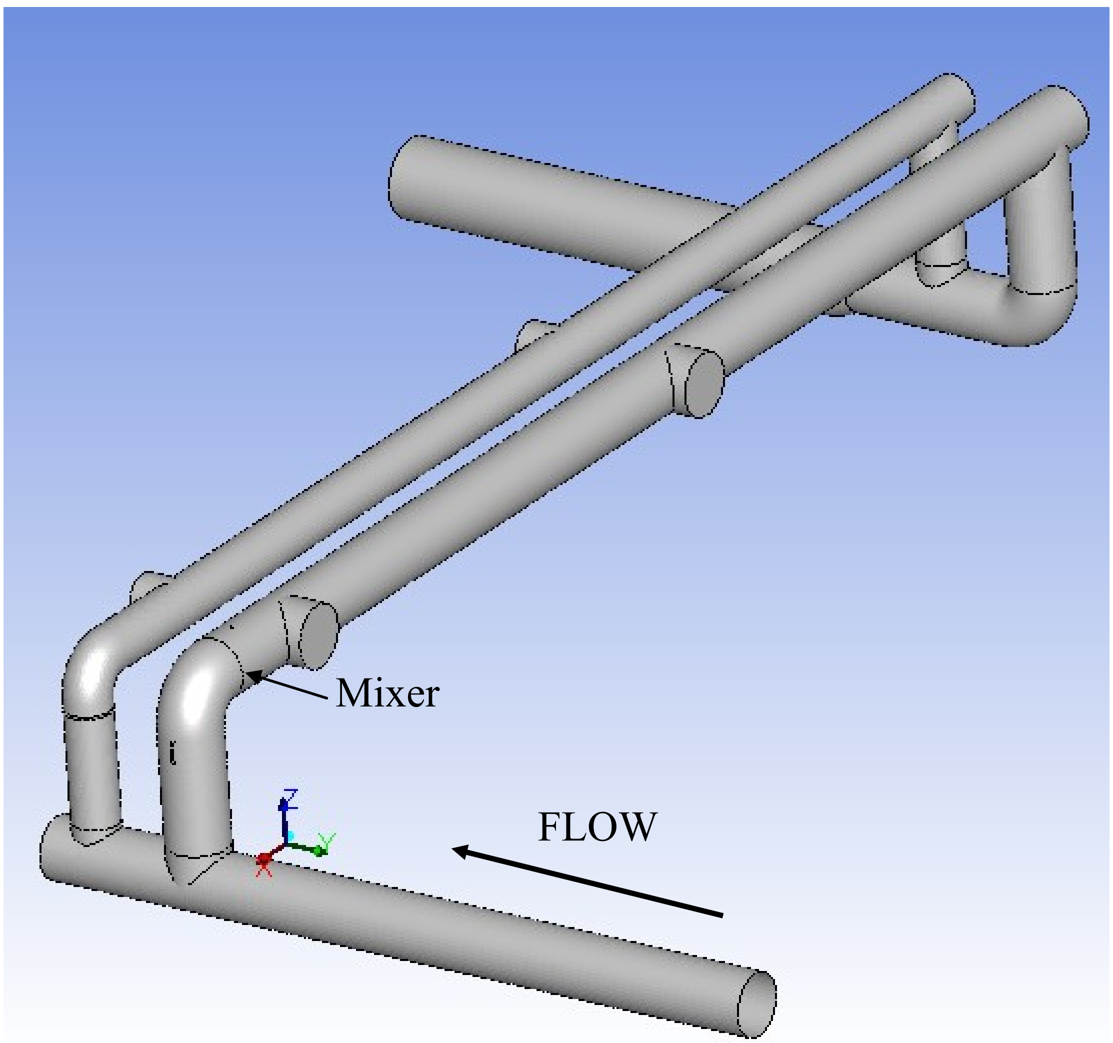


Figure 1 - CFD Model Domain, Standing at NE, Looking SW

The maximum expected system flow rate of 45.0-MGD was analyzed in order to evaluate the pressure loss of the mixer as well as the mixing effectiveness.

The 0.8-beta Westfall 2800 mixer was placed between the flanges at the 90° bend outlet just downstream of the butterfly valve as the pipe comes above grade. Mixing effectiveness was tested with the mixer tabs arranged both horizontally and vertically (Figure 2).

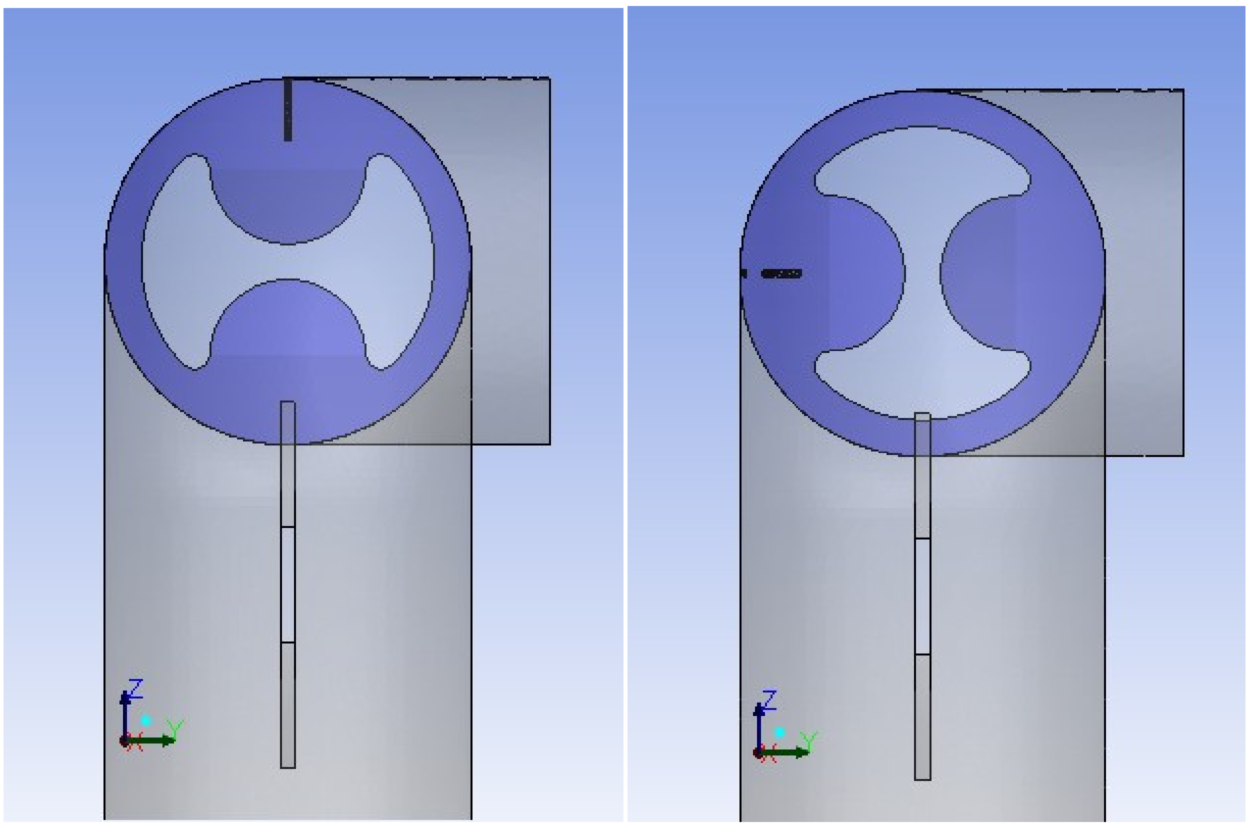


Figure 2 - 48" Mixer Orientation Vertical (Left) and Horizontal (Right). View is from the North, Looking South.

Also included in the model, visible in Figure 2, is the fully opened butterfly valve upstream of the mixer.

A sodium hypochlorite solution was injected through 1-inch pipes, inserted 8" beyond the pipe wall. The sodium hypochlorite solution was injected at a rate of 7.2-gpm, for an average mixed-out concentration of 230-ppmv. Two injection lance locations were evaluated for mixing effectiveness, and maximum concentration on the face of the mixer as well as the pipe walls.

The injection locations were located:

1. Within the mixer flange directly downstream of the mixer, behind a tab centerline.
2. 0.5D (24”) downstream of the mixer, again behind a tab centerline.

The water and sodium hypochlorite solution were treated as separate, fully miscible fluids, with viscosity and density values at an assumed temperature of 68°F. The results are presented as mass fraction of sodium hypochlorite (NaOCl), and similarly mixing is presented as coefficient of variation (CoV) of NaOCl, where a perfectly mixed solution would have a CoV = 0.

RESULTS AND DISCUSSION

The goal of the 2800 mixer is to achieve a uniform concentration of the injected material within a short downstream distance while meeting the maximum pressure loss criteria. The multiple out-of-plane pipe bends directly upstream of the mixer cause a biased flow distribution entering the mixer, so in order to ensure optimal mixing in this specific application, the mixer was tested in two orientations – horizontal and vertical.

The pressure loss attributable to the mixer in each orientation was calculated by subtracting the system pressure loss (the difference between the static pressure at the model inlet and outlet) with the mixer, compared to the same pipe configuration without the mixer. In the vertical orientation the mixer added 86-iwc of pressure loss; and in the horizontal orientation the mixer added 88-iwc of pressure loss. Both of these values are greater than the maximum specified pressure loss of 6.49-ft or 77.9-iwc (Section 11240, Part 2.1c). The pressure loss of the 2800 mixer installed in this location is somewhat higher than it would be if installed in a straight run of pipe at the same flow rate (78-iwc) due to the non-uniform velocity profile entering the mixer caused by the pipe bends and butterfly valve.

In applications with hard water, injection of sodium hypochlorite directly downstream of the 2800 mixer has been known to cause significant scale buildup on the back face of the mixer. This is thought to be caused by precipitation of Calcium-based solids in an alkaline environment where the local concentration of sodium hypochlorite is high. The injection quill placement at locations downstream is intended to reduce the local alkalinity on the back face of the mixer as well as the pipe wall so that scale buildup is avoided, or at least significantly reduced.

It was found that placing the injection quill downstream did notably decrease the maximum sodium hypochlorite concentration on the downstream side of the mixer in both the vertical and horizontal mixer orientation (Figure 3). When injected 0.5D downstream of the mixer plate (location 2), the maximum NaOCl concentration was found to be roughly 10 times the average concentration; whereas when the injection was directly downstream of the mixer plate (location 1), the maximum NaOCl concentration was more than 200 times the average concentration.

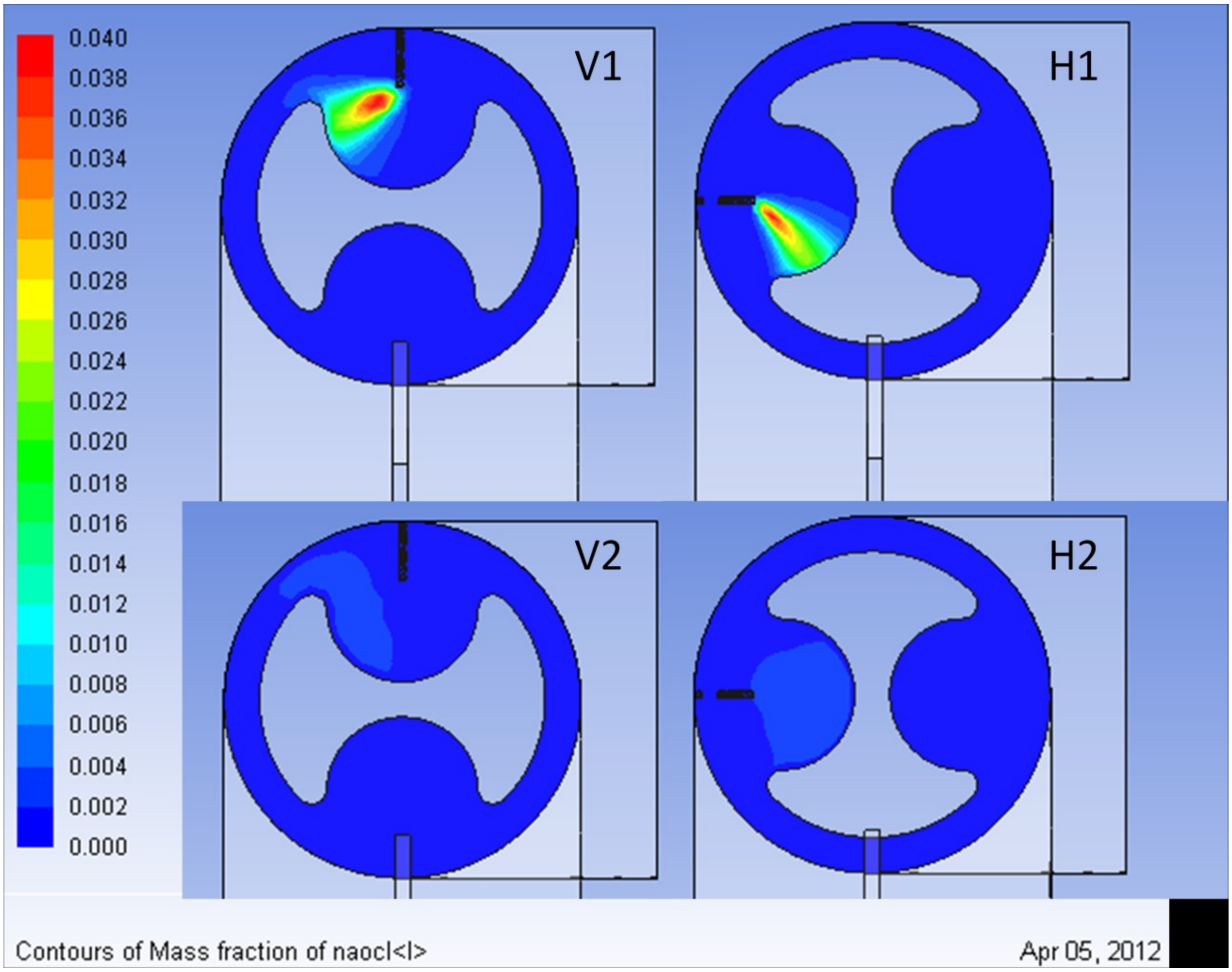


Figure 3 - NaOCl Concentration (Mass Fraction) on Downstream Face of Mixer for Each Case.

The reason the downstream placement of the lance works is the area of reversed flow behind each mixer tab brings the injected fluid back towards the mixer where it can be blended with the water, rather than traveling downstream away from the mixer (Figure 4). The injection location should not be placed more than 0.5D downstream of the mixer, because as the injection point moves further downstream, the strength of the reversed flow diminishes, and the mixing performance will decrease.

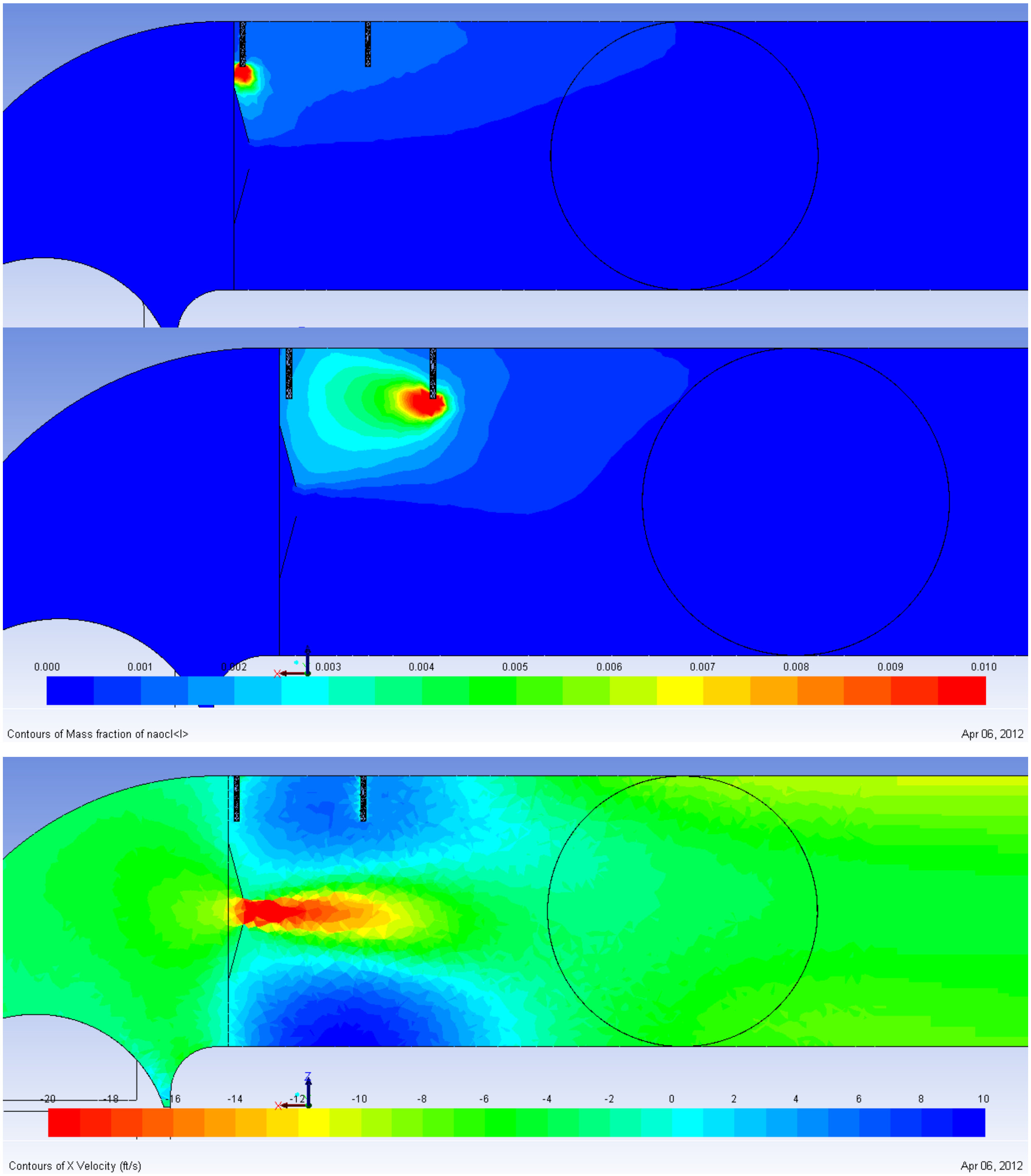


Figure 4 – 48" Pipe Centerline Contour Plots of NaOCl Concentration (Mass Fraction) for Case V1 (top), Case V2 (middle), and X-Velocity with the Vertical Mixer (bottom)

The concentration coefficient of variation (CoV) was measured at several planes downstream of the mixer (Figure 5, Figure 6), and for every configuration tested, the CoV was found to be 0.001 or less by the time the flow reached the model outlet.

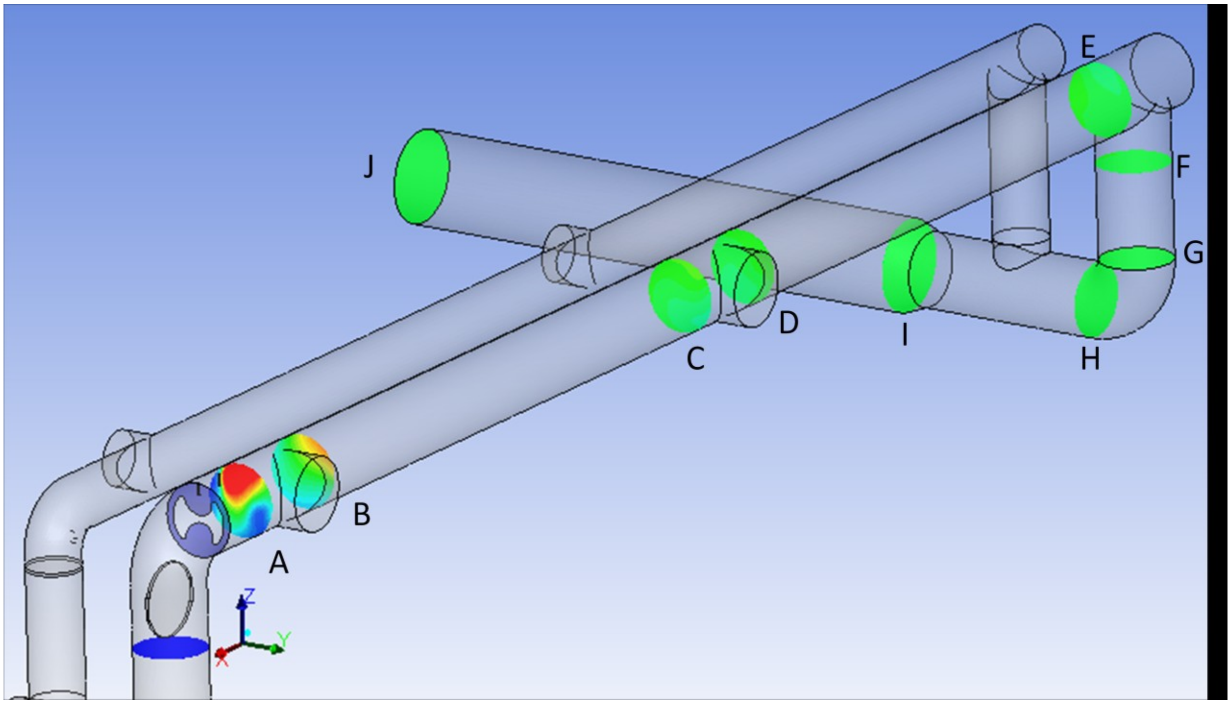


Figure 5 - Test Plane Locations

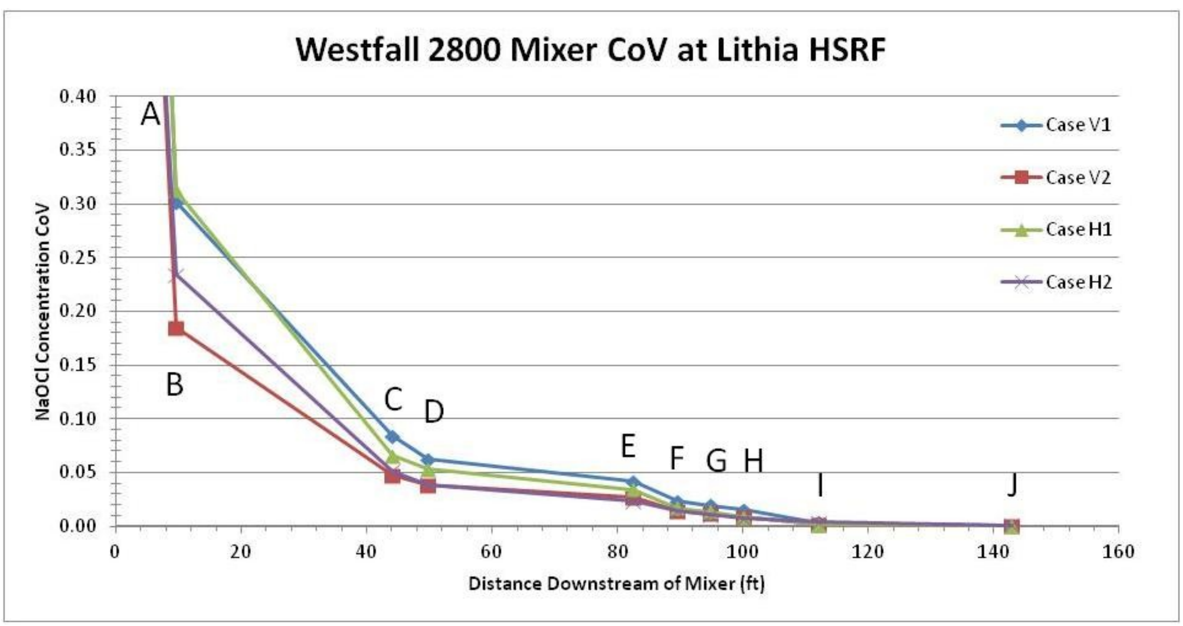


Figure 6 - NaOCl CoV Downstream of Mixer

The tabulated results for all quantities evaluated in each case are presented in Table 1.

Table 1 - Lithia HSRF Westfall 2800 Mixer Results

0.8-Beta Westfall 2800 Mixer	Case V1	Case V2	Case H1	Case H2
Water Flow Rate (MGD)	45.0	45.0	45.0	45.0
NaOCl Flow Rate (gpm)	7.2	7.2	7.2	7.2
Final NaOCl Concentration (ppmv)	230	230	230	230
Mixer Orientation	Vertical	Vertical	Horizontal	Horizontal
Injection Distance from Mixer (in)	2	24	2	24
Mixer Pressure Loss (inwg)	86	86	88	88
Max NaOCl Concentration on:	**Case V1**	**Case V2**	**Case H1**	**Case H2**
Mixer Face (ppmv)	61,501	2,364	51,647	2,717
Pipe Wall (ppmv)	2,180	3,433	1,647	1,894
NaOCl Concentration CoV at Plane:	**Case V1**	**Case V2**	**Case H1**	**Case H2**
A	1.1000	0.8650	1.0323	0.8227
B	0.3017	0.1848	0.3125	0.2344
C	0.0838	0.0472	0.0661	0.0514
D	0.0625	0.0385	0.0530	0.0388
E	0.0413	0.0265	0.0342	0.0231
F	0.0236	0.0139	0.0170	0.0141
G	0.0195	0.0114	0.0136	0.0108
H	0.0153	0.0086	0.0086	0.0077
I	0.0034	0.0016	0.0019	0.0038
J	0.0003	0.0002	0.0005	0.0010

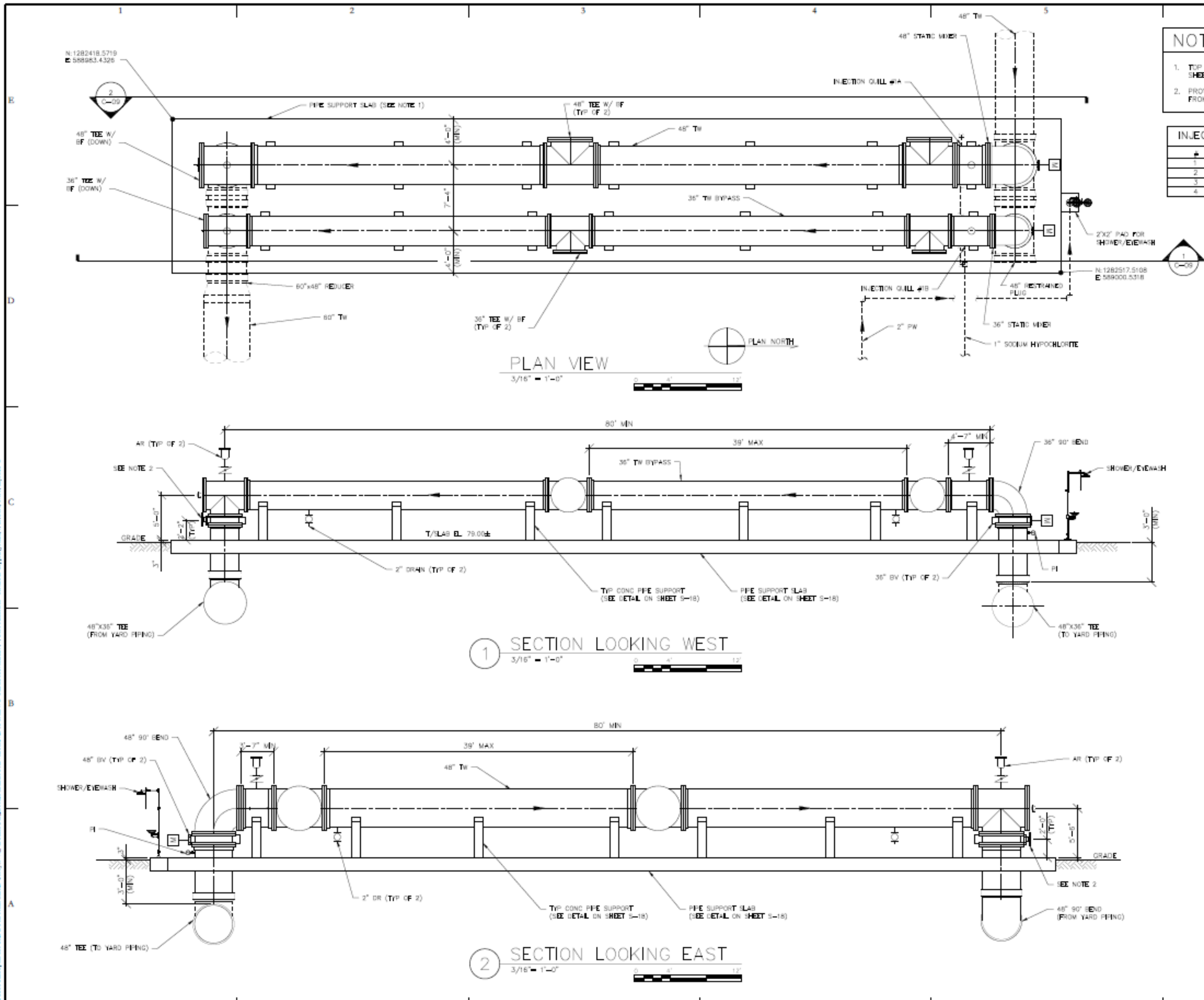
CONCLUSIONS

The 48-inch 0.8-beta Westfall 2800 mixer was found to mix the flow very well in the piping layout at the Lithia HSRF. The mixer was tested at maximum flow, however the mixing results are expected to be similar at all flow rates throughout the expected range (7.5-45.0 MGD) since the flow will be turbulent across the entire flow range (Re > 4,600).

The pressure loss of the 0.8-beta Westfall 2800 mixer was found to be 86-iwc in the vertical orientation, and 88-iwc in the horizontal orientation, which are both greater than the specified 78-iwc (6.49-ft) maximum head loss at the maximum flow rate.

By installing the injection lance 0.5D downstream of the mixer, the maximum concentration on the downstream face of the mixer was significantly reduced compared to the standard injection location directly downstream of the mixer. This should help to minimize scale buildup in installations with hard water.

Though all configurations were found to mix down to a CoV of 0.001 or less within the 60-inch outlet pipe, the configuration with the best results is installing the mixer with the tabs in the vertical orientation, and the injection nozzle 24-inches downstream of the mixer.



NOTES

1. TOP OF SLAB ELEVATIONS SHALL BE AS SHOWN ON SHEET C-12.
2. PROVIDE EXTENDED SHAFT TO ENSURE CLEARANCE FROM CONNECTING FLANGES ON TEE.

INJECTOR QUILL TYPE LEGEND

#	CHEMICAL
1	SODIUM HYPOCHLORITE
2	AQUA AMMONIA
3	LIQUID POLYPHOSPHATE
4	HYDROFLUOROSILICIC ACID

TAMPA BAY WATER
Supplying Water To The Region
2575 ENTERPRISE ROAD
CLEARWATER, FLORIDA 33763
727.796.2355
WWW.TAMPABAYWATER.ORG

PROJECT NO.: 06503

VEOLIA WATER
MALCOLM PIRNIE | ARCADIS
The Water Division of ARCADIS
CERTIFICATE OF AUTHORIZATION NO. 67
14025 RIVEREDGE DR. SUITE 600
TAMPA, FLORIDA 33637

SEALS

ANDRE A. DIEFFENTHALLER, P.E. DATE
LIC. NO. 49928

LITHIA, FLORIDA

HYDROGEN SULFIDE REMOVAL FACILITY

CONFORMED DRAWINGS

REV.	DATE	DESCRIPTION	BY

COPYRIGHT:
DATE: SEPTEMBER 2011
PROJECT NO.: 6740002
FILE NAME: C-106
DESIGNED BY: J. COPPOLA
DRAWN BY: M. CALZON
CHECKED BY: J. COPPOLA
APPROVED BY: A. DIEFFENTHALLER

SHEET TITLE

CIVIL

SODIUM HYPOCHLORITE INJECTION PIPING ASSEMBLY PLAN AND SECTIONS

SCALE: AS SHOWN

C-09

SHEET 9 OF 21