COMPUTATIONAL FLOW MODEL OF WESTFALL'S 3050 STAGED MIXER

AGM-10-R-17

By

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Submitted to:

WESTFALL MANUFACTURING COMPANY

June 2010

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INTRODUCTION

Alden Research Laboratory Inc. (Alden) was contracted by Westfall Manufacturing Inc. (Westfall) to evaluate the performance of the 3050 mixer with 1, 2, and 3 stages. The objective of this mixer is to achieve a low coefficient of variation (CoV) of the injected fluid within a short distance downstream of the injection point, with as little pressure loss as possible. This report discusses the head loss and mixing capabilities of the leading tab low head mixer installed in a 6-inch pipe, with water flowing at 360-gpm.

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 approximately 2-3 million hexahedral and tetrahedral cells.

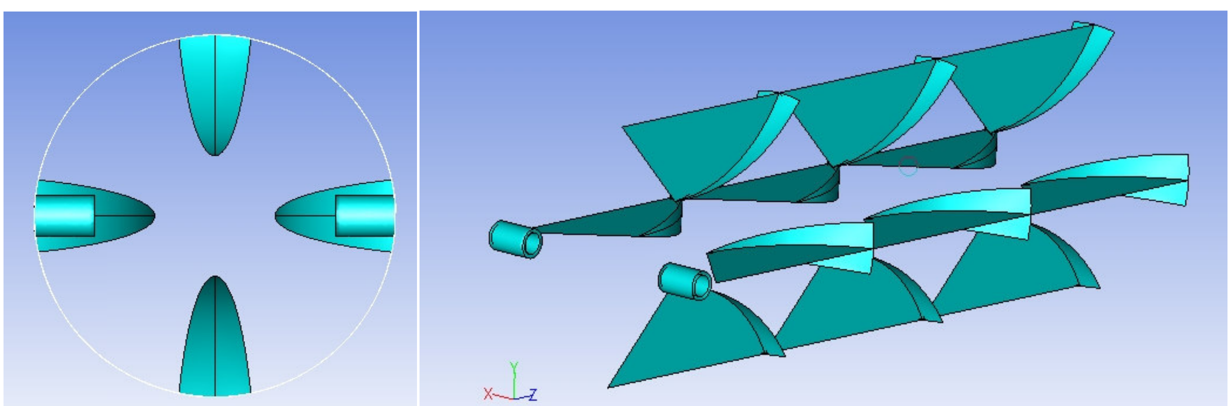
Numerical simulations were performed using the CFD software package FLUENT 12.1, a state-of-the-art, finite volume-based fluid flow simulation package including program modules for boundary condition specification, problem setup, and solution phases of a flow analysis. Advanced turbulence modeling techniques, 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 three-dimensional, incompressible, turbulent flow through the pipe and around the flow conditioner. A stochastic, anisotropic, two-equation k-ε model was used to simulate the turbulence. The anisotropic model was required to properly resolve the secondary flows that developed as a result of changes in geometry. Detailed descriptions of the physical models employed in each of the Fluent modules are available from Ansys/Fluent, the developer of Fluent V12.1.

MODEL BOUNDARY CONDITIONS

The tests were conducted in 6-inch I.D steel pipe. It has been determined through previous testing that the mixer performs similarly at different flow rates, provided the flow is turbulent, so only one water flow rate was tested (360 gpm) at ambient pressure and temperature. A uniform velocity inlet was imposed at the model inlet, which was placed 5 pipe diameters upstream of the mixer inlet with a tracer concentration of 0%. A uniform static pressure boundary condition was imposed at the model outlet, which was placed 10 pipe diameters downstream of the mixer inlet so that the impact of the mixer could be documented as a function of downstream distance. On all surfaces, no-slip impermeable adiabatic wall boundary conditions were applied with roughness heights set to 0.00015-ft as appropriate for steel pipe.

To measure mixing, a 2% solution (7.2 gpm) of a tracer fluid with properties equal to that of water was injected equally into two opposing 3/8" schedule-40 injection nozzles directly upstream of the mixer inlet. The injection nozzles protruded 1-inch into the pipe, or 1/6 of the pipe diameter, or ½ the height of the mixing tabs. The mixing of the solution was then monitored at 1 diameter (6") intervals downstream.



Injection nozzle location with triple mixer configuration.

RESULTS AND DISCUSSION

The goal of the mixer is to achieve a uniform concentration of the injected material in as short a downstream distance as possible, with as little pressure loss as possible.

Pressure loss was measured across the flow conditioner by comparing pressure loss across the test section with and without the conditioner installed. K-values were calculated from the resulting pressure measurements, and do not include either the pressure loss for the pipe under normal flow conditions, or the resistance from the injection nozzles. The following k-values may be used to calculate the pressure loss contribution of the mixer at other flow conditions.

Westfall 3050 Staged Mixer

Configuration	k-Value
Single Mixer:	0.58
Double Mixer:	
In Line	1.13
45° Offset	1.03
Triple Mixer:	
In Line	1.64

Mixing was tested in four configurations: a single mixer; a double mixer with subsequent mixing tabs aligned with the flow (in line); a double mixer with subsequent mixing tabs offset by 45°; and a triple mixer with subsequent mixing tabs aligned with the flow (in line). After testing the double mixer, it was found that the in line orientation performed better than the 45° offset orientation, so for the triple mixer only the in line configuration was tested.

As expected, adding stages to the mixer increased performance, with the exception of the double mixer with 45° offset after 7 diameters downstream. The 45° offset configuration is not recommended. A plot of the CoV of concentration is presented at the end of the report, along with color contours and pathlines for various mixer configurations. A table of CoV values is provided below.

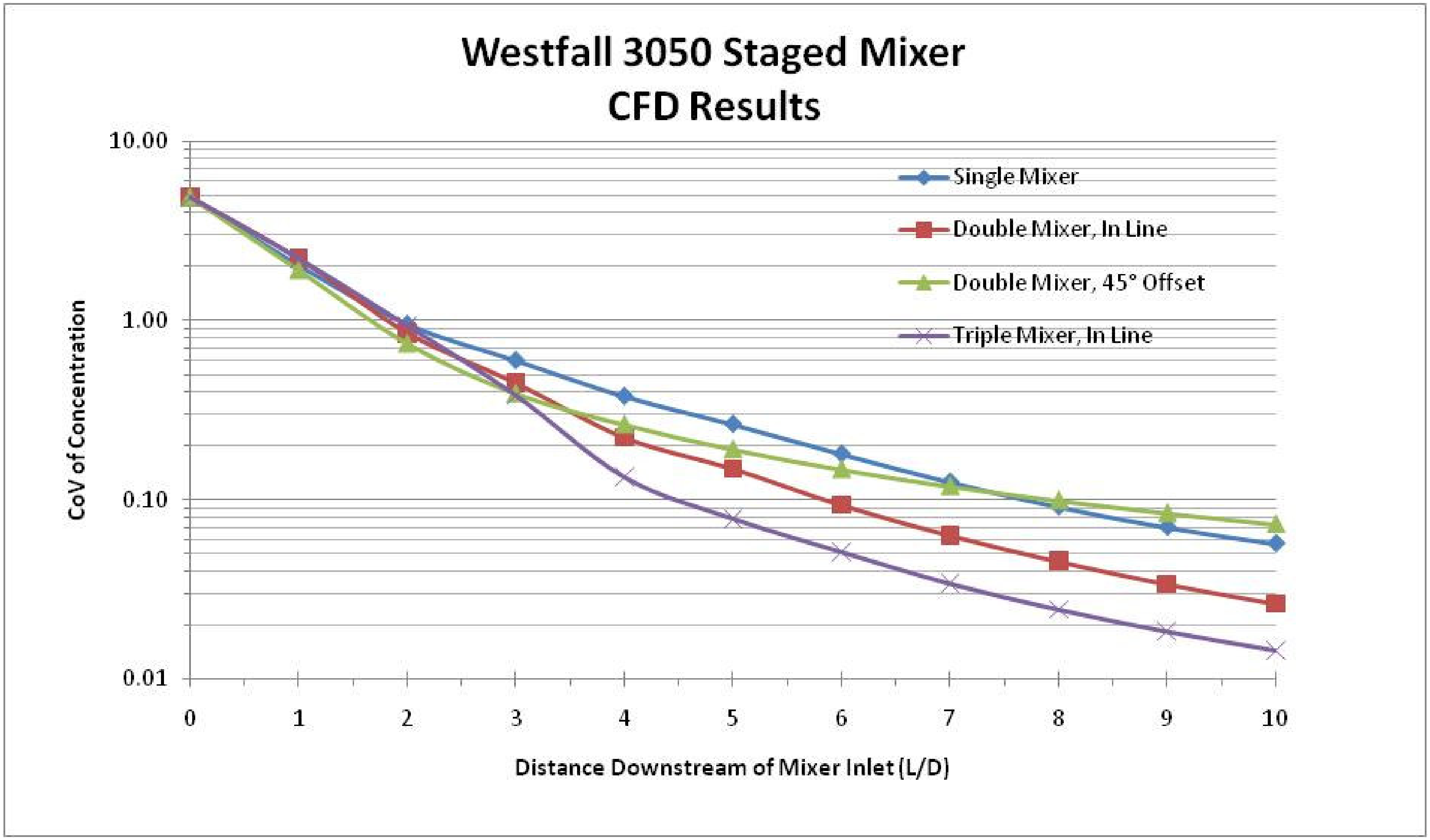
Westfall 3050 Staged Mixer Concentration CoV:

L/D	Single Mixer	Double Mixer In Line	Double Mixer 45° Offset	Triple Mixer In Line
0	4.871	4.871	4.871	4.871
1	2.027	2.217	1.909	2.217
2	0.952	0.854	0.744	0.935
3	0.598	0.449	0.391	0.382
4	0.377	0.223	0.263	0.134
5	0.263	0.149	0.191	0.078
6	0.180	0.094	0.147	0.051
7	0.125	0.063	0.119	0.034
8	0.091	0.045	0.099	0.024
9	0.070	0.034	0.084	0.018
10	0.057	0.026	0.073	0.014

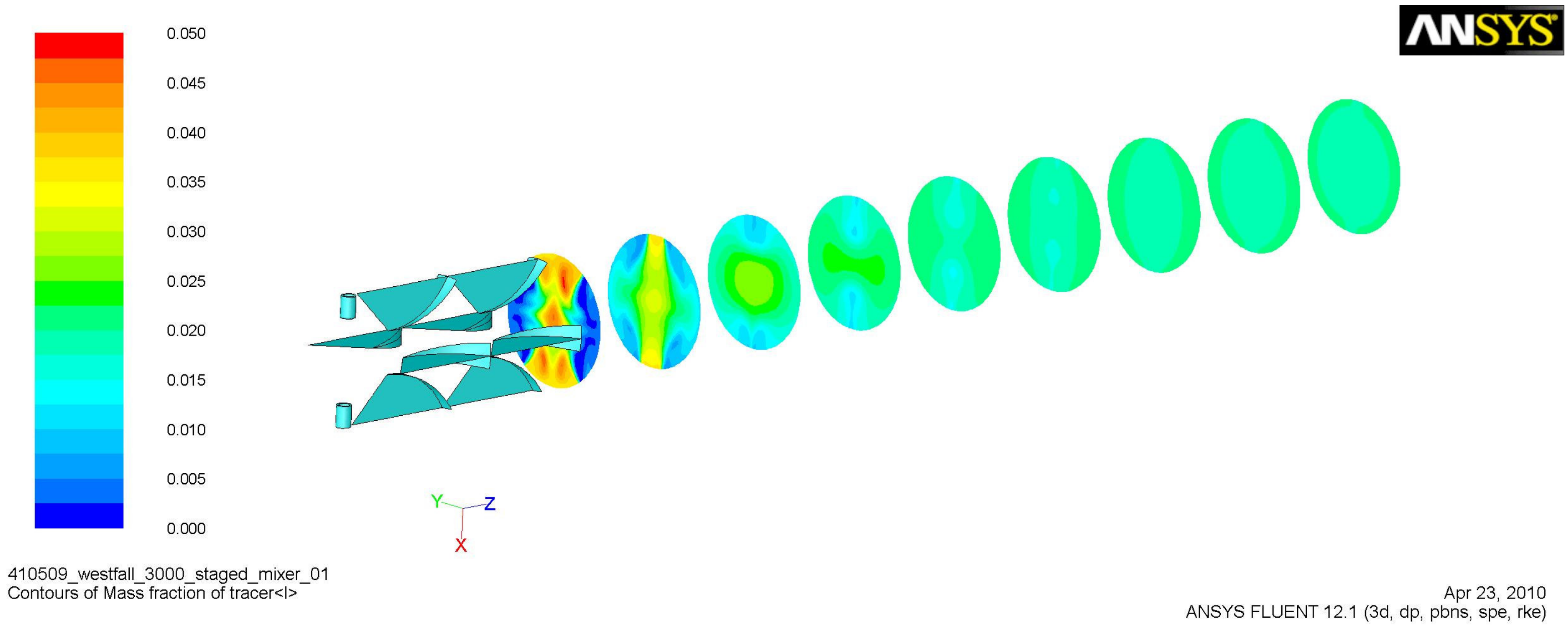
CONCLUSIONS

With the injection locations described, the Westfall 3050 mixer works quite well in low-head applications provided there are a few pipe diameters available downstream for the flow to mix fully. Since the device was originally designed as a flow conditioner, it is also very effective at mitigating any swirling flow. The low pressure loss characteristics are very desirable for pressure limited operation, and the raked angles prevent fouling.

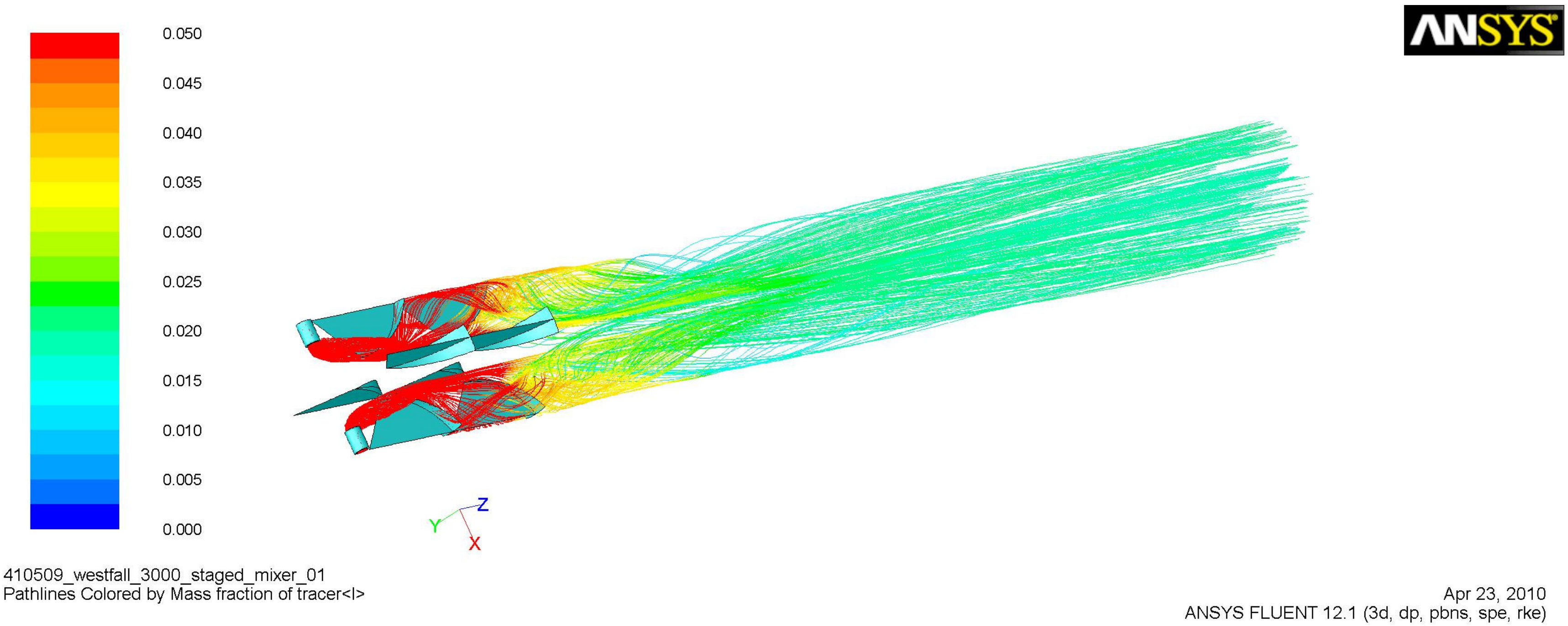
Adding more mixers increases the mixing performance, though at the cost of increased pressure loss. It is recommended that subsequent mixers be aligned with one another, and not offset, as the offset orientation was found to impede mixing.



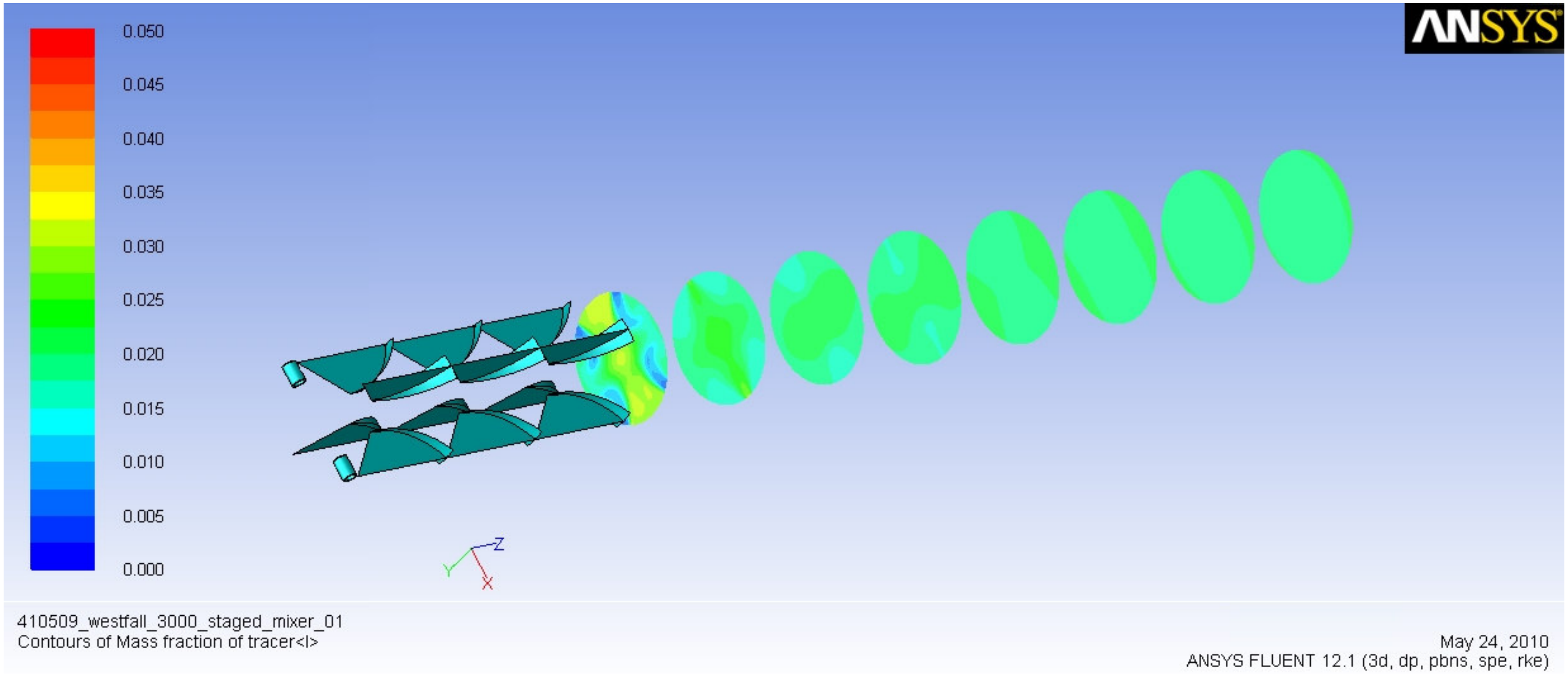
CoV of Concentration in a 6-in ID steel pipe with 2 opposing injection ports, and a mixed tracer concentration of 2%.



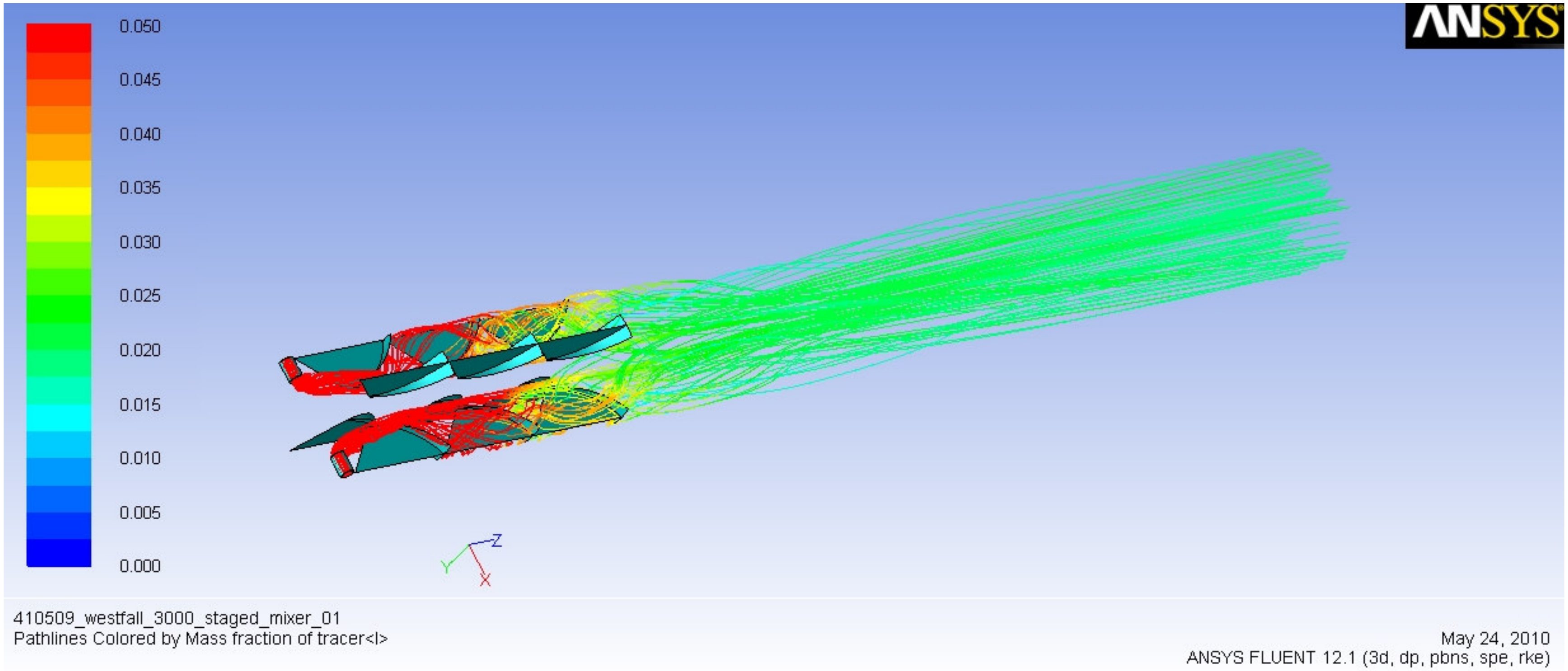
Profiles of concentration downstream of double in line 3050 mixer. Average concentration = 0.02



Pathlines from injection ports colored by concentration downstream of double in line 3050 mixer. Average concentration = 0.02



Profiles of concentration downstream of triple in line 3050 mixer. Average concentration = 0.02



Pathlines from injection ports colored by concentration downstream of triple in line 3050 mixer. Average concentration = 0.02

WESTFALL MANUFACTURING CO.

HEADLOSS CHART

pipe ID ***6.07*** ***inches***

GPM	CFS	ft/s	MODEL 2800 0.7 BETA psi Head loss	MODEL 2800 0.8 BETA psi Head loss	MODEL 2800 0.9 BETA psi Head loss	MODEL 3050 SINGLE psi Head loss	MODEL 3050 DOUBLE psi Head loss	MODEL 3050 TRIPLE psi Head loss
100	0.223	1.11	0.27	0.11	0.06	0.005	0.009	0.014
200	0.446	2.22	1.08	0.45	0.22	0.018	0.037	0.054
300	0.668	3.33	2.42	1.01	0.50	0.041	0.084	0.122
400	0.891	4.43	4.31	1.80	0.90	0.074	0.149	0.217
500	1.114	5.54	6.74	2.82	1.40	0.115	0.234	0.339
600	1.337	6.65	9.70	4.06	2.02	0.166	0.336	0.488
700	1.560	7.76	13.20	5.52	2.75	0.226	0.458	0.664
800	1.782	8.87	17.24	7.21	3.59	0.295	0.598	0.868
900	2.005	9.98	21.82	9.13	4.54	0.373	0.757	1.098
1000	2.228	11.09	26.94	11.27	5.61	0.460	0.934	1.356
1100	2.451	12.20	32.60	13.63	6.78	0.557	1.130	1.640
1200	2.674	13.30	38.79	16.22	8.07	0.663	1.345	1.952

m3/hr	m3/s	m/s	0.7 BETA kg/cm2 head loss	0.8 BETA kg/cm2 head loss	0.9 BETA kg/cm2 head loss	MODEL 3050 SINGLE kg/cm2	MODEL 3050 DOUBLE kg/cm2	MODEL 3050 TRIPLE kg/cm2
23	0.0063	0.338	0.019	0.008	0.004	0.0003	0.0007	0.0010
45	0.0126	0.676	0.076	0.032	0.016	0.0013	0.0026	0.0038
68	0.0189	1.014	0.171	0.071	0.036	0.0029	0.0059	0.0086
91	0.0252	1.352	0.303	0.127	0.063	0.0052	0.0105	0.0153
114	0.0315	1.689	0.474	0.198	0.099	0.0081	0.0164	0.0239
136	0.0379	2.027	0.683	0.286	0.142	0.0117	0.0237	0.0344
159	0.0442	2.365	0.929	0.389	0.193	0.0159	0.0322	0.0468
182	0.0505	2.703	1.214	0.508	0.253	0.0207	0.0421	0.0611
204	0.0568	3.041	1.536	0.642	0.320	0.0263	0.0533	0.0773
227	0.0631	3.379	1.897	0.793	0.395	0.0324	0.0658	0.0954
250	0.0694	3.717	2.295	0.960	0.477	0.0392	0.0796	0.1155
273	0.0757	4.055	2.731	1.142	0.568	0.0467	0.0947	0.1374