COMPUTATIONAL FLOW MODEL OF
WESTFALL'S 2800 MIXER
AGM-10-R-01

By

Kimbal A. Hall, PE

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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 assess the mixing performance of Westfall's 2800 mixer at a range of velocities. The following is a summary of the findings.

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 1.5 million hexahedral and tetrahedral cells.

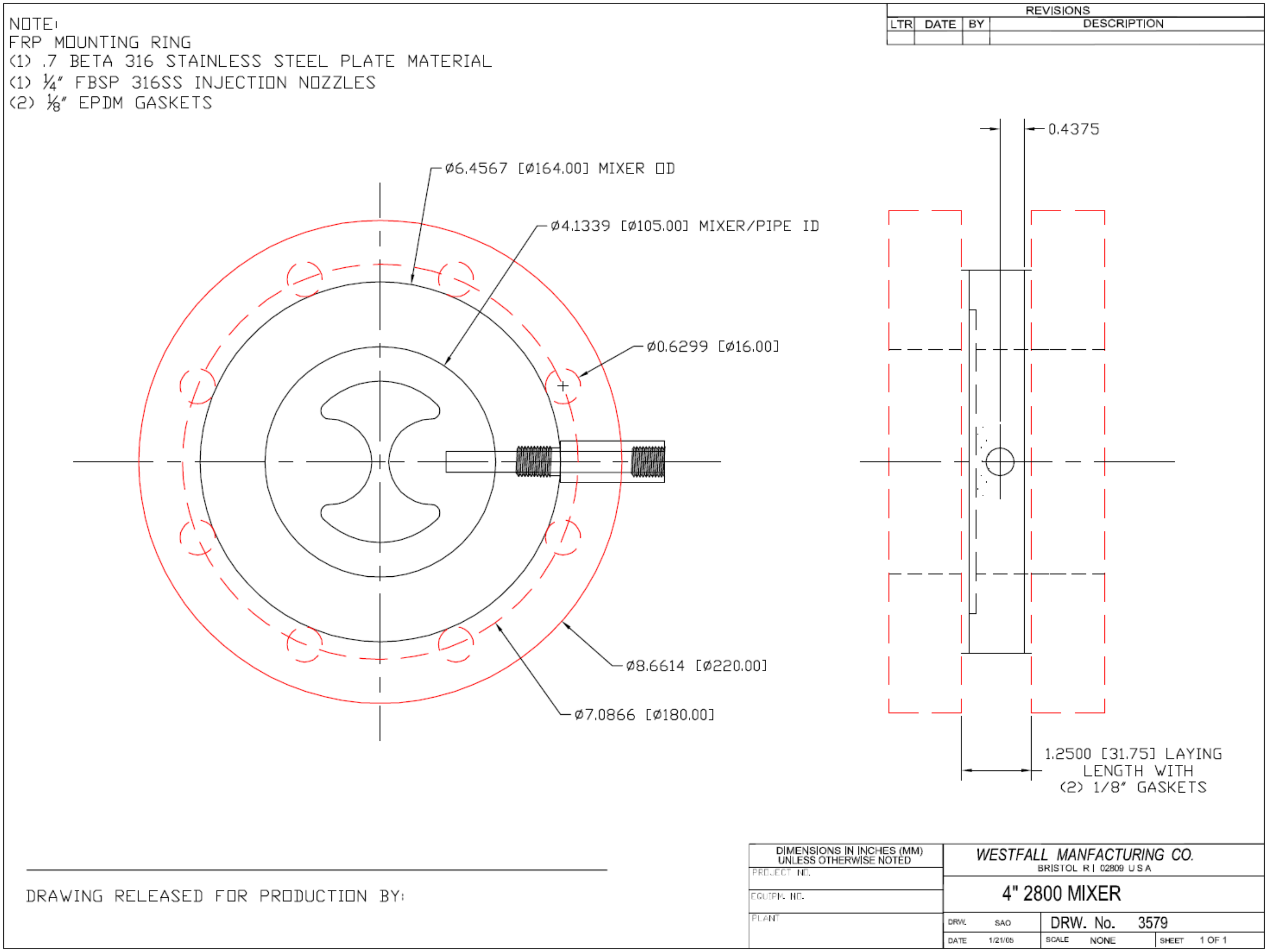
Numerical simulations were performed using the CFD software package FLUENT V6.3.26, a state-of-the-art, finite volume-based fluid flow simulation package including program modules for boundary condition specification, problem setup, and solution phases of a flow analysis. Advanced turbulence modeling 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 mixer. 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 Fluent, Inc., the developer of Fluent V6.3.26.

MODEL BOUNDARY CONDITIONS

Westfall provided dimensioned drawings of their 2800 mixer to be placed in a 100mm pipe. The tests were simulated in water at full scale. The test section consisted of a 40 diameter straight pipe section with the mixer located in the center. A uniform velocity inlet was imposed at the test section inlet, and the flow was allowed to reach a nearly fully-developed flow profile before it reached the mixer. A uniform static pressure boundary was imposed at the model outlet. On all surfaces, no-slip impermeable adiabatic wall boundary conditions were applied with roughness heights set to 0.0002-ft as appropriate for smooth steel pipe. Ten (10) flow rates of water at ambient pressure and temperature were tested ranging from 0.1-m/s to 1.0-m/s in 0.1-m/s increments.

An injection nozzle was located downstream of only one of the mixer's tabs, which injected a 1% mass flow of a tracer fluid. The tracer fluid was of similar temperature and density as water, and was fully miscible.


NOTE:
FRP MOUNTING RING
(1) .7 BETA 316 STAINLESS STEEL PLATE MATERIAL
(1) ¼" FBSP 316SS INJECTION NOZZLES
(2) ⅛" EPDM GASKETS
REVISIONS
LTR
DATE
BY
DESCRIPTION
Ø6.4567 [Ø164.00] MIXER OD
Ø4.1339 [Ø105.00] MIXER/PIPE ID
Ø0.6299 [Ø16.00]
Ø8.6614 [Ø220.00]
Ø7.0866 [Ø180.00]
0.4375
1.2500 [31.75] LAYING LENGTH WITH (2) 1/8" GASKETS
DRAWING RELEASED FOR PRODUCTION BY:
DIMENSIONS IN INCHES (MM) UNLESS OTHERWISE NOTED
PROJECT NO.
EQUIPM. NO.
PLANT
WESTFALL MANFACTURING CO.
BRISTOL R I 02809 U S A
4" 2800 MIXER
DRW. SAO
DRW. No. 3579
DATE 1/21/05
SCALE NONE
SHEET 1 OF 1

RESULTS AND DISCUSSION

The mixer performance is judged by the Coefficient of Variation (CoV) of tracer fluid downstream of the mixing device. The results presented here pertain to water at ambient temperature and pressure.

Even at the lowest flow rate of 0.1-m/s, the flow through the pipe is still turbulent (Re = 9,420). As such, the flow characteristics (i.e. – k-value, mixing rate, turbulence intensity, etc) are expected to remain substantially the same down to the transition regime (Re < 4000, or V = 0.043-m/s). This is indeed the case, and is clearly shown by the CoV of tracer fluids at various points downstream at the different flow rates (Figure 1).

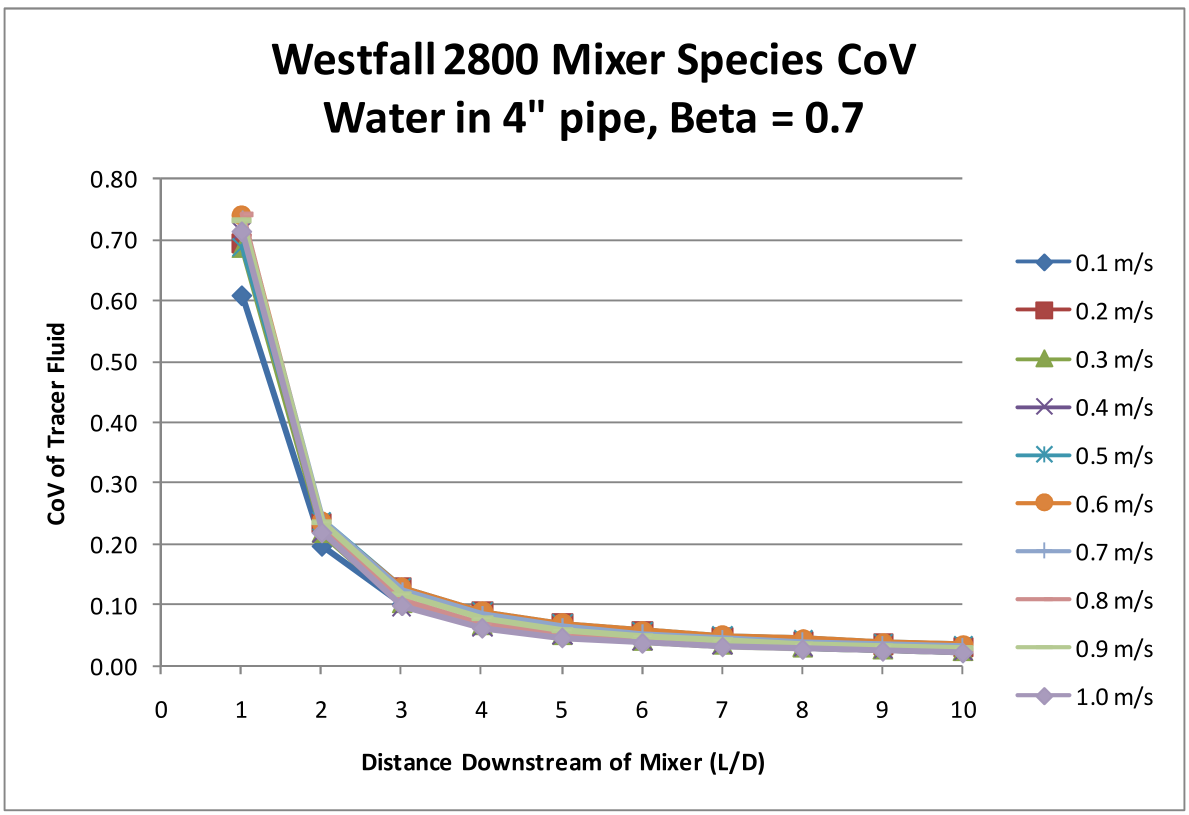


Figure 1: CoV of tracer fluid downstream of mixer.

The flow through the mixer creates two jets through the open sections, which are angled towards the wall. The high velocity jets create a strong recirculation zone behind the mixer that extends approximately 3 diameters downstream, which is where the bulk of the mixing occurs (Figure 3).

With the dosing port behind only one tab, there is a clear asymmetry in the region immediately downstream of the mixer (Figure 4, Figure 5). Some of the tracer fluid migrates over to the un-dosed side in the wake of the thinner segment near the wall. The amount of dosing fluid that migrates to the opposing side will likely be less with larger-beta mixers. It is expected that two dosing ports (one behind each tab) will result in better mixing at short distances downstream, but will not change results much farther downstream.

Though it is likely already known, the k-value for the mixer was also calculated (k-value = 29.2). The expected pressure loss through the mixer is plotted for all test points in Figure 2.

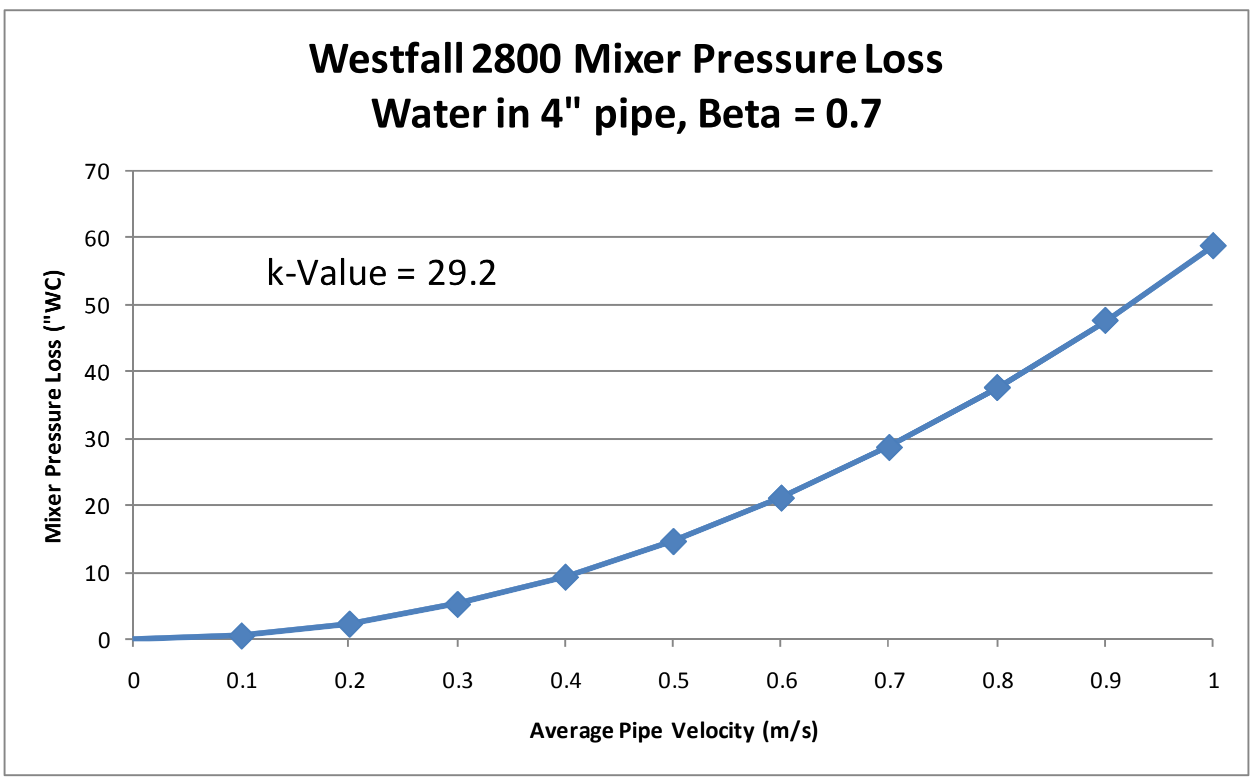


Figure 2: Pressure loss of mixer at various flow rates.

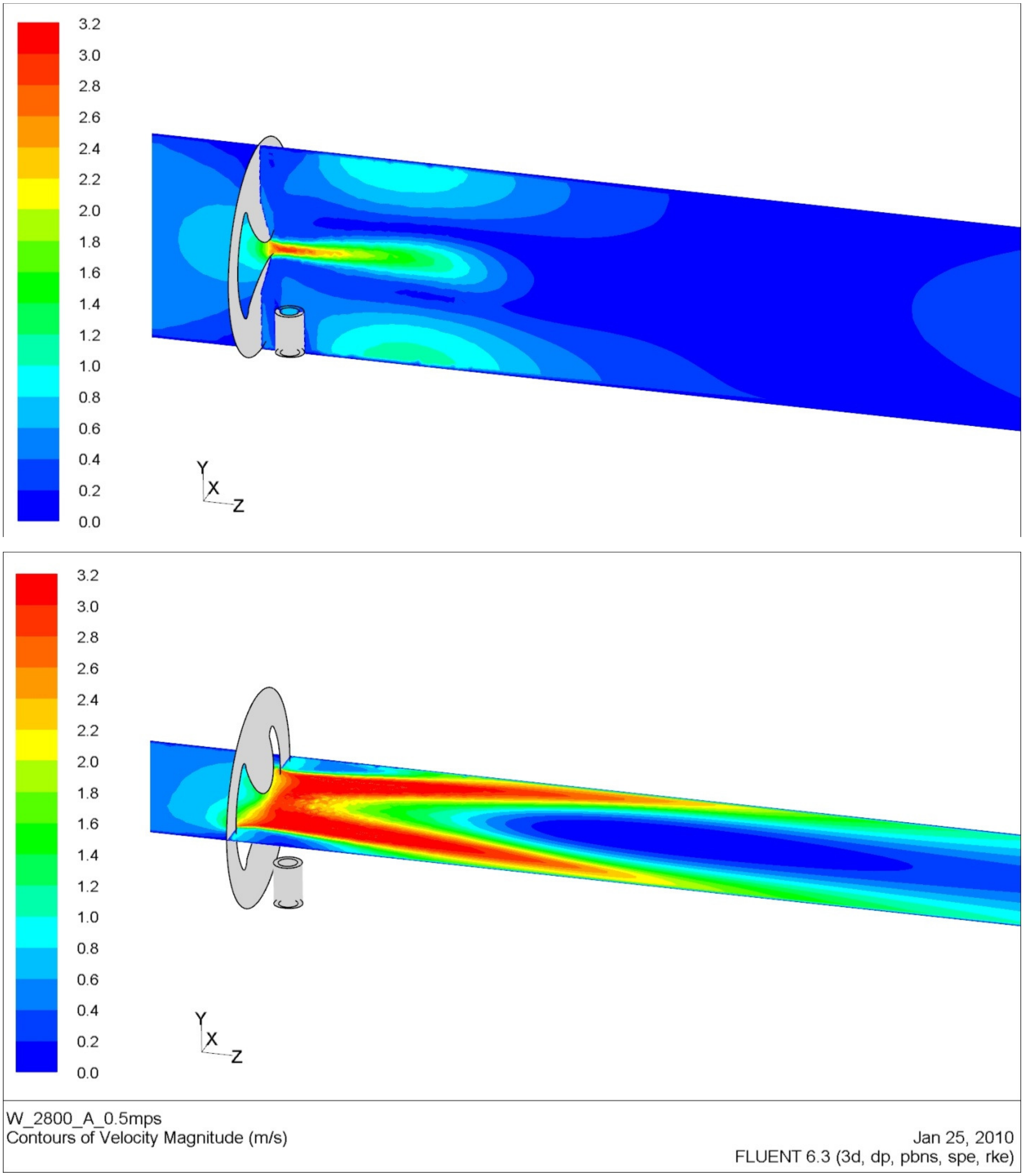


Figure 3: Color contours of velocity magnitude (m/s) Average velocity = 0.5 m/s.

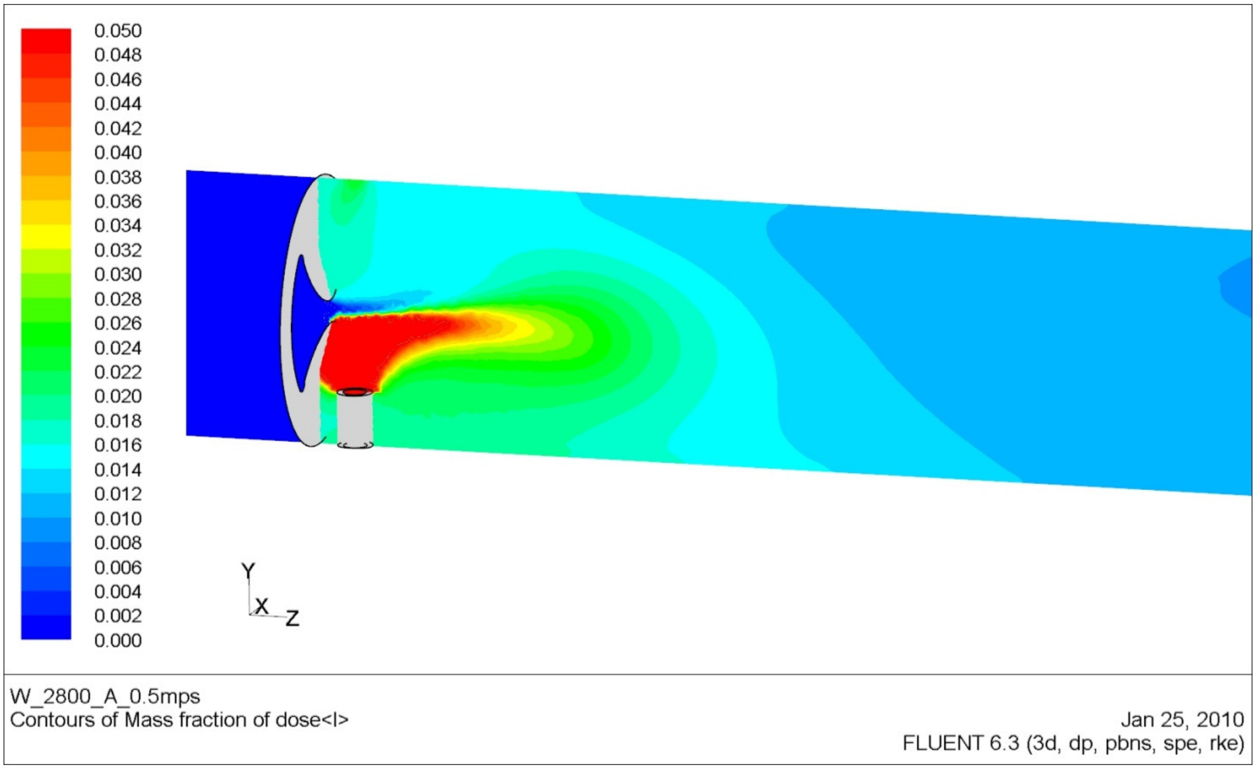


Figure 4: Contours of tracer fluid mass fraction (average value = 0.01)

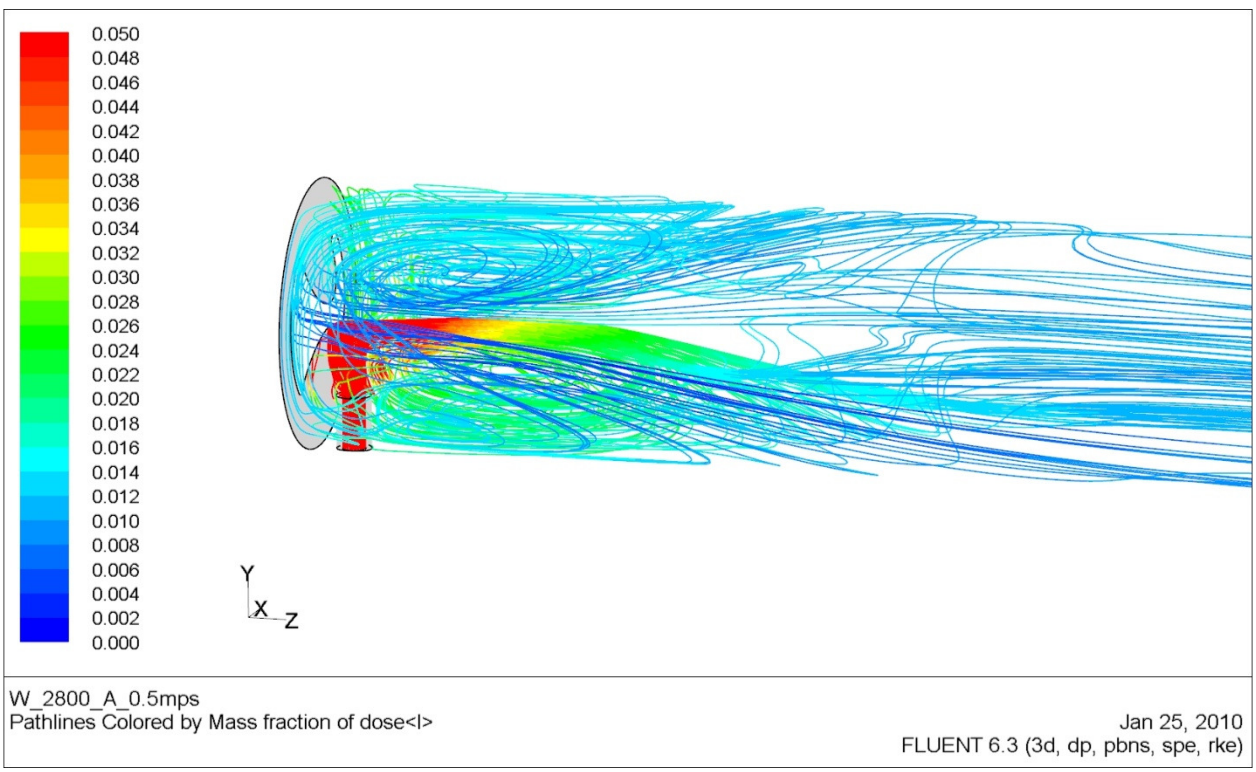


Figure 5: Pathlines released from the dosing port, colored by tracer mass fraction (average value = 0.01)