

MIXING TESTS OF A 6" STATIC MIXER
ASSEMBLY COMPRISED OF A 0.9 BETA MIXER PLATE
AND AN ADJUSTABLE 0.7 BETA MIXER PLATE
FOR
WESTFALL MANUFACTURING COMPANY
PURCHASE ORDER NUMBER 05-2981
REPORT NUMBER 059-05/C805

PROPRIETARY

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A static mixing device was tested at Alden, for Westfall Manufacturing Company, using Alden's standard test procedures, QA-AGF-7-86 Revision 3. The purpose of testing was to define mixing effectiveness and overall head loss. The static mixer consisted of two shaped orifice plates with a 0.25" diameter injection port behind the upstream plate as shown in Figure 1. The second plate, two pipe diameters downstream from the first plate, was mounted such that it could be rotated about the horizontal axis (in Figure 1).

The twin mixer assembly was tested for mixing efficiency under Westfall Manufacturing Company Purchase Order Number 05-2981. The purpose of the testing was to define the mixing effectiveness of the twin plate assembly. The upstream mixer plate beta ratio was 0.9 (ratio of open to total area) and the downstream plate was 0.7. Mixing tests were performed with the downstream plate closed to the flow, at angles to the flow, and parallel to the flow. The assembly was tested in standard 6" pipe. Head loss measurements of the mixing assembly were performed under a separate Purchase Order Number 05-2957 and results may be found in Alden Report Number ARL No. 051-05/C805, which describes the method used to determining flow. Testing was continuation of tests conducted at Alden in 1995 and 2004, which documented mixing of single mixing plates in a 6" pipe.

Figure 1 illustrates the alignment of the mixer plate lobes relative to the numbered sampling ports. Sampling was performed in a plane ten diameters downstream of the mixer with three sampling locations on each of four radii, with sampling ports were located as shown in Figure 2. The previously used sampling equipment for the 6" line was used. Procedures were essentially identical to the earlier mixing tests. The dye tracer injection flow was injected at 0.5 gpm into port 1 of the upstream mixer plate for all tests.

TEST RESULTS

Spatial distribution of tracer concentration was measured for each test condition in Table 1. Table 1 lists the description, flow and average flow velocity, and the coefficient of variation (CoV). A plot of CoV versus pipe velocity and mixer configuration is provided in Figure 3.

Individual concentration measurements for each test condition are listed for each sample port in Tables 2 through 8. For tests 5 through 7, the flow was established to produce 3 psi head loss across the mixer assembly with the downstream plate rotated to full open, 45 degrees and 22.5 degrees from closed. Since the response of the fluorometer is linear with concentration, the sample voltage minus background voltage, is directly proportional to concentration. Measured voltage is listed for each sample port, and the relative concentration at each port is calculated as the voltage minus the average background voltage. The deviation of each relative concentration from the mean concentration of the twelve port readings is listed as percent of the mean. The coefficient of variation (CoV) is defined as the standard deviation of the concentrations at the twelve locations divided by the mean concentration.

TABLE 1
Mixing Test Condition Summary

| Test ID Number | Description | Total Flow (gpm) | Area Average Velocity ft./sec | CoV |
|-------------------|---|---------------------|----------------------------------|-------|
| 1 | Downstream plate closed and aligned with upstream plate | 45 | 0.5 | 0.008 |
| 2 | " | 90 | 1.0 | 0.009 |
| 3 | " | 277 | 3.1 | 0.009 |
| 4 | Downstream plate closed and rotated 90 deg. with respect to upstream plate | 271 | 3.1 | 0.007 |
| 5 | Downstream plate open (parallel to flow), flow set to generate 3psi head loss across mixer assembly | 712 | 8.1 | 0.033 |
| 6 | Downstream plate 45 deg. from closed, flow set to generate 3psi head loss across mixer assembly | 579 | 6.6 | 0.012 |
| 7 | Downstream plate 22.5 deg. From closed, flow set to generate 3psi head loss across mixer assembly | 425 | 4.8 | 0.008 |

TABLE 2
Test Condition 1

Injection: Mixer port # 1

Beta: 0.9 & 0.7

Sample

at: 10D downstream of mixer

Flow: 45 GPM

| <u>Location</u> | <u>Output Voltage</u> | <u>Background Concentration</u> | <u>Relative Concentration</u> | <u>Deviation</u> |
|-----------------|---------------------------|-------------------------------------|-----------------------------------|------------------|
| 1 | 1.9088 | 0.0284 | 1.8804 | 0.0% |
| 2 | 1.8923 | 0.0284 | 1.8639 | -0.9% |
| 3 | 1.8853 | 0.0284 | 1.8569 | -1.3% |
| 4 | 1.9089 | 0.0284 | 1.8805 | 0.0% |
| 5 | 1.9172 | 0.0284 | 1.8888 | 0.4% |
| 6 | 1.9288 | 0.0284 | 1.9004 | 1.0% |
| 7 | 1.9254 | 0.0284 | 1.8970 | 0.9% |
| 8 | 1.9002 | 0.0284 | 1.8718 | -0.5% |
| 9 | 1.9206 | 0.0284 | 1.8922 | 0.6% |
| 10 | 1.9268 | 0.0284 | 1.8984 | 0.9% |
| 11 | 1.9021 | 0.0284 | 1.8737 | -0.4% |
| 12 | 1.8955 | 0.0284 | 1.8671 | -0.7% |
| Average: | | 0.0284 | 1.8809 | |
| Standard | | | | |
| Deviation: | | | 0.0145 | |
| CoV: | | | 0.0077 | |

TABLE 3
Test Condition 2

| Injection: Mixer port # 1 | | | | |
|-----------------------------|-----------------------|---------------------------------|-------------------------------|------------------|
| Beta: 0.9 & 0.7 | | | | |
| Sample | | | | |
| at: 10D downstream of mixer | | | | |
| Flow: 90 GPM | | | | |
| <u>Location</u> | <u>Output Voltage</u> | <u>Background Concentration</u> | <u>Relative Concentration</u> | <u>Deviation</u> |
| 1 | 1.7224 | 0.0465 | 1.6760 | -1.4% |
| 2 | 1.7469 | 0.0465 | 1.7005 | 0.0% |
| 3 | 1.7247 | 0.0465 | 1.6783 | -1.3% |
| 4 | 1.7427 | 0.0465 | 1.6963 | -0.2% |
| 5 | 1.7574 | 0.0465 | 1.7110 | 0.7% |
| 6 | 1.7764 | 0.0465 | 1.7300 | 1.8% |
| 7 | 1.7490 | 0.0465 | 1.7026 | 0.2% |
| 8 | 1.7421 | 0.0465 | 1.6957 | -0.2% |
| 9 | 1.7477 | 0.0465 | 1.7013 | 0.1% |
| 10 | 1.7313 | 0.0465 | 1.6849 | -0.9% |
| 11 | 1.7647 | 0.0465 | 1.7183 | 1.1% |
| 12 | 1.7478 | 0.0465 | 1.7014 | 0.1% |
| Average: | | 0.0465 | 1.6996 | |
| Standard Deviation: | | | 0.0156 | |
| CoV: | | | 0.0092 | |

TABLE 4
Test Condition 3

| Injection: Mixer port # 1 | | | | |
|-----------------------------|-----------------------|---------------------------------|-------------------------------|------------------|
| Beta: 0.9 & 0.7 | | | | |
| Sample | | | | |
| at: 10D downstream of mixer | | | | |
| Flow: 277 GPM | | | | |
| <u>Location</u> | <u>Output Voltage</u> | <u>Background Concentration</u> | <u>Relative Concentration</u> | <u>Deviation</u> |
| 1 | 1.7234 | 0.0891 | 1.6343 | -0.6% |
| 2 | 1.7368 | 0.0891 | 1.6477 | 0.2% |
| 3 | 1.7268 | 0.0891 | 1.6377 | -0.4% |
| 4 | 1.7560 | 0.0891 | 1.6669 | 1.4% |
| 5 | 1.7529 | 0.0891 | 1.6638 | 1.2% |
| 6 | 1.7399 | 0.0891 | 1.6508 | 0.4% |
| 7 | 1.7260 | 0.0891 | 1.6369 | -0.4% |
| 8 | 1.7396 | 0.0891 | 1.6505 | 0.4% |
| 9 | 1.7258 | 0.0891 | 1.6367 | -0.4% |
| 10 | 1.7466 | 0.0891 | 1.6575 | 0.8% |
| 11 | 1.7085 | 0.0891 | 1.6194 | -1.5% |
| 12 | 1.7154 | 0.0891 | 1.6263 | -1.1% |
| Average: | | 0.0891 | 1.6440 | |
| Standard | | | | |
| Deviation: | | | 0.0146 | |
| CoV: | | | 0.0089 | |

TABLE 5
Test Condition 4

| Injection: Mixer port # 1 | | | | |
|--------------------------------------|----------------|--------------------------|------------------------|-----------|
| Beta: 0.9 & 0.7, 90 degree alignment | | | | |
| Sample | | | | |
| at: 10D downstream of mixer | | | | |
| Flow: 271 GPM | | | | |
| Location | Output Voltage | Background Concentration | Relative Concentration | Deviation |
| 1 | 1.7777 | 0.0799 | 1.6979 | -0.6% |
| 2 | 1.7874 | 0.0799 | 1.7076 | -0.1% |
| 3 | 1.7856 | 0.0799 | 1.7058 | -0.2% |
| 4 | 1.8008 | 0.0799 | 1.7210 | 0.7% |
| 5 | 1.8178 | 0.0799 | 1.7380 | 1.7% |
| 6 | 1.7855 | 0.0799 | 1.7057 | -0.2% |
| 7 | 1.7929 | 0.0799 | 1.7131 | 0.3% |
| 8 | 1.7816 | 0.0799 | 1.7018 | -0.4% |
| 9 | 1.7768 | 0.0799 | 1.6970 | -0.7% |
| 10 | 1.7867 | 0.0799 | 1.7069 | -0.1% |
| 11 | 1.7889 | 0.0799 | 1.7091 | 0.0% |
| 12 | 1.7807 | 0.0799 | 1.7009 | -0.5% |
| Average: | | 0.0799 | 1.7087 | |
| Standard | | | | |
| Deviation: | | | 0.0113 | |
| CoV: | | | 0.0066 | |

TABLE 6
Test Condition 5

| Injection: Mixer port # 1 | | | | |
|--------------------------------------|-----------------------|---------------------------------|-------------------------------|------------------|
| Beta: 0.9 & 0.7, 0.7 mixer open 100% | | | | |
| Sample at: 10D downstream of mixer | | | | |
| Flow: 712 GPM | | | | |
| <u>Location</u> | <u>Output Voltage</u> | <u>Background Concentration</u> | <u>Relative Concentration</u> | <u>Deviation</u> |
| 1 | 1.6342 | 0.0283 | 1.6059 | -5.2% |
| 2 | 1.6540 | 0.0283 | 1.6257 | -4.0% |
| 3 | 1.6694 | 0.0283 | 1.6411 | -3.1% |
| 4 | 1.7568 | 0.0283 | 1.7285 | 2.0% |
| 5 | 1.7798 | 0.0283 | 1.7515 | 3.4% |
| 6 | 1.8235 | 0.0283 | 1.7952 | 6.0% |
| 7 | 1.7173 | 0.0283 | 1.6890 | -0.3% |
| 8 | 1.7100 | 0.0283 | 1.6817 | -0.7% |
| 9 | 1.7046 | 0.0283 | 1.6763 | -1.1% |
| 10 | 1.6975 | 0.0283 | 1.6692 | -1.5% |
| 11 | 1.7707 | 0.0283 | 1.7424 | 2.8% |
| 12 | 1.7536 | 0.0283 | 1.7253 | 1.8% |
| Average: | | 0.0283 | 1.6943 | |
| Standard Deviation: | | | 0.0559 | |
| CoV: | | | 0.0330 | |

TABLE 7
Test Condition 6

| Injection: Mixer port # 1 | | | | |
|--|-----------------------|---------------------------------|-------------------------------|------------------|
| Beta: 0.9 & 0.7, downstream plate @ 45 degrees | | | | |
| Sample | | | | |
| at: 10D downstream of mixer | | | | |
| Flow: 579 GPM | | | | |
| <u>Location</u> | <u>Output Voltage</u> | <u>Background Concentration</u> | <u>Relative Concentration</u> | <u>Deviation</u> |
| 1 | 1.7998 | 0.0139 | 1.7859 | 1.1% |
| 2 | 1.8117 | 0.0139 | 1.7978 | 1.7% |
| 3 | 1.7975 | 0.0139 | 1.7836 | 0.9% |
| 4 | 1.7717 | 0.0139 | 1.7578 | -0.5% |
| 5 | 1.7510 | 0.0139 | 1.7371 | -1.7% |
| 6 | 1.7536 | 0.0139 | 1.7397 | -1.6% |
| 7 | 1.7518 | 0.0139 | 1.7379 | -1.7% |
| 8 | 1.7804 | 0.0139 | 1.7665 | 0.0% |
| 9 | 1.7801 | 0.0139 | 1.7662 | -0.1% |
| 10 | 1.7879 | 0.0139 | 1.7740 | 0.4% |
| 11 | 1.7966 | 0.0139 | 1.7827 | 0.9% |
| 12 | 1.7926 | 0.0139 | 1.7787 | 0.6% |
| Average: | | 0.0139 | 1.7673 | |
| Standard Deviation: | | | 0.0204 | |
| CoV: | | | 0.012 | |

TABLE 8
Test Condition 7

| Injection: Mixer port # 1 | | | | |
|--|-----------------------|---------------------------------|-------------------------------|------------------|
| Beta: 0.9 & 0.7, downstream plate @ 22.5 degrees | | | | |
| Sample at: 10D downstream of mixer | | | | |
| Flow: 425 GPM | | | | |
| <u>Location</u> | <u>Output Voltage</u> | <u>Background Concentration</u> | <u>Relative Concentration</u> | <u>Deviation</u> |
| 1 | 1.8493 | 0.0106 | 1.8388 | -1.9% |
| 2 | 1.8831 | 0.0106 | 1.8726 | -0.1% |
| 3 | 1.8767 | 0.0106 | 1.8662 | -0.4% |
| 4 | 1.9059 | 0.0106 | 1.8954 | 1.1% |
| 5 | 1.9020 | 0.0106 | 1.8915 | 0.9% |
| 6 | 1.8960 | 0.0106 | 1.8855 | 0.6% |
| 7 | 1.8939 | 0.0106 | 1.8834 | 0.5% |
| 8 | 1.8810 | 0.0106 | 1.8705 | -0.2% |
| 9 | 1.8803 | 0.0106 | 1.8698 | -0.2% |
| 10 | 1.8792 | 0.0106 | 1.8687 | -0.3% |
| 11 | 1.8864 | 0.0106 | 1.8759 | 0.1% |
| 12 | 1.8787 | 0.0106 | 1.8682 | -0.3% |
| Average: | | 0.0106 | 1.8738 | |
| Standard Deviation: | | | 0.0147 | |
| CoV: | | | 0.008 | |

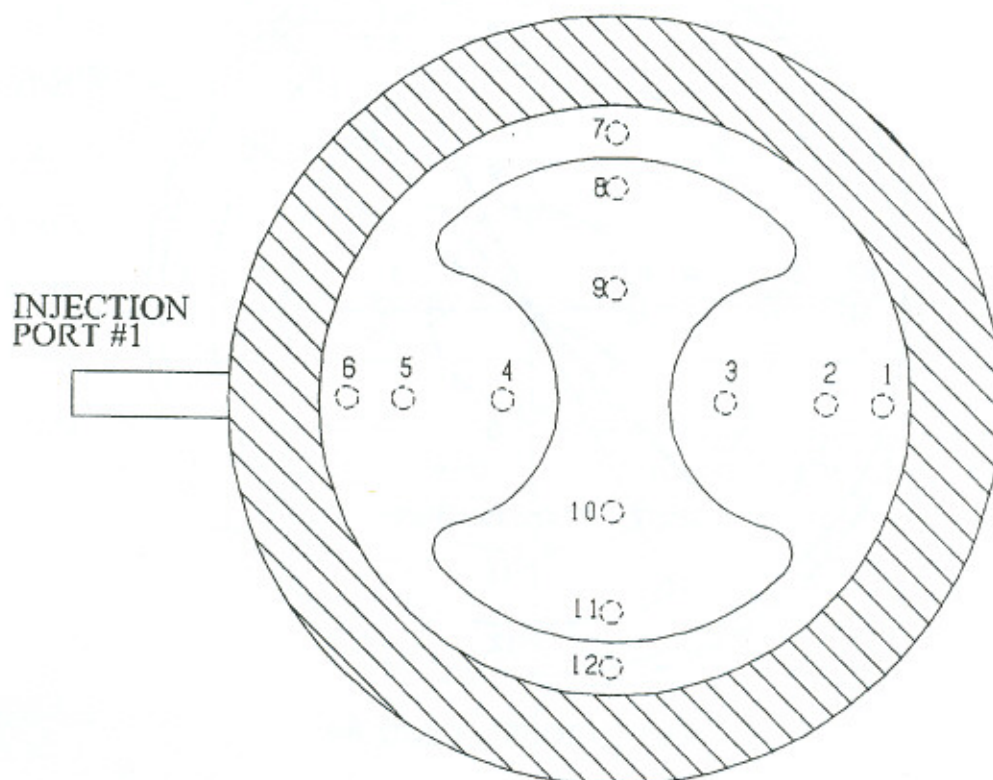


FIGURE 1 MIXER PLATE INSTALLATION

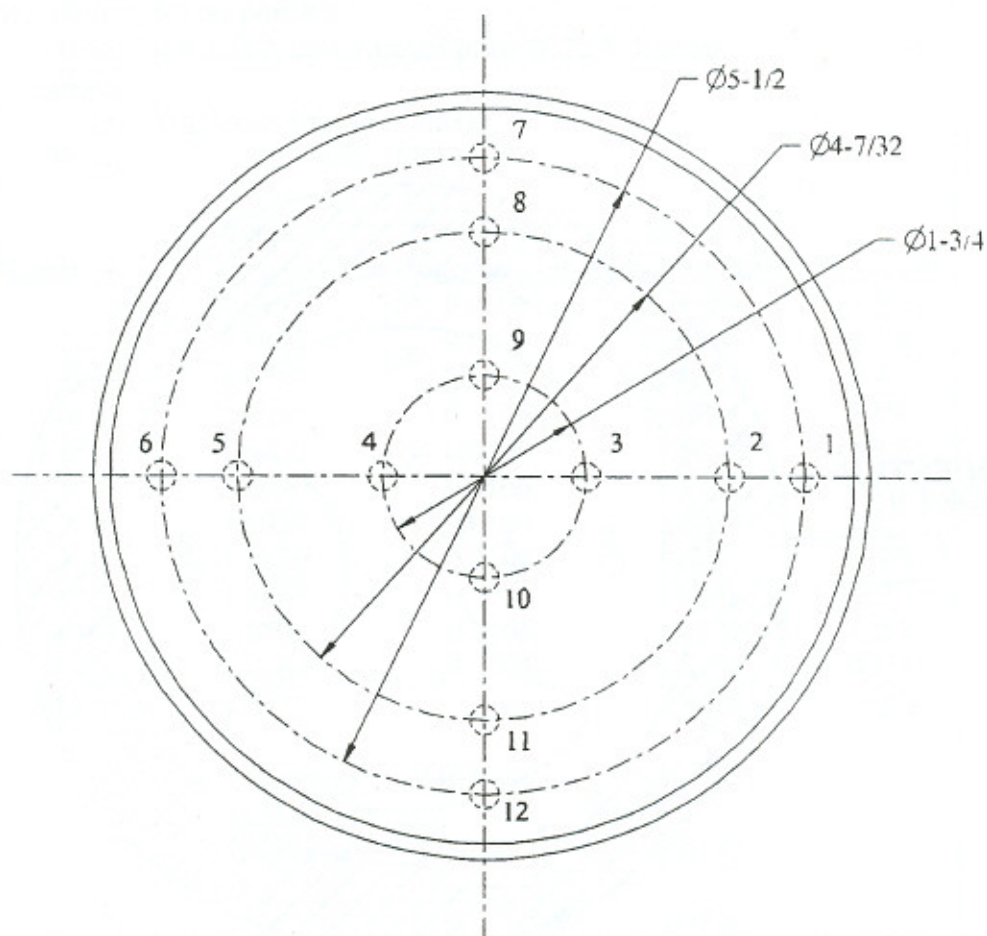


FIGURE 2 SAMPLING PORT LOCATIONS

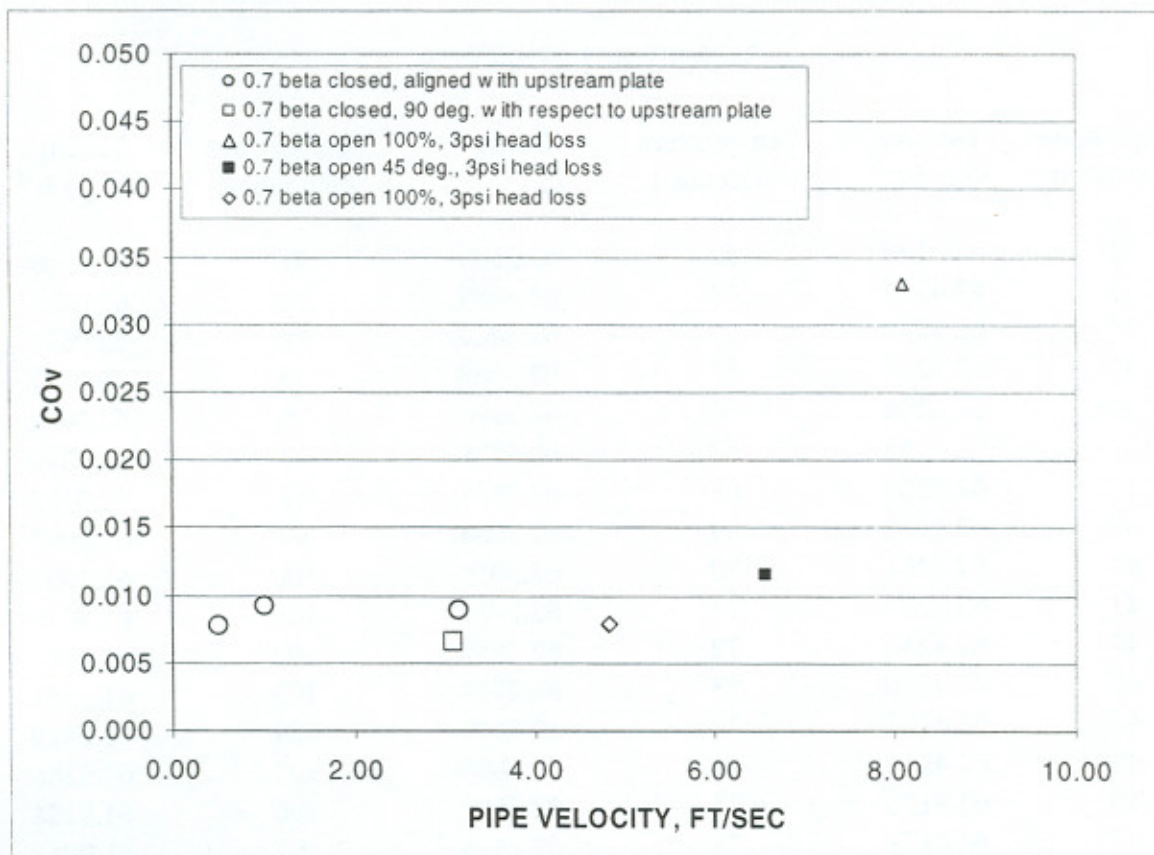


FIGURE 3 PLOT OF CoV