Storm Mixer
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Determining the Mixing Efficiency of a Static Mixer using Coefficient of Variation (CoV) Analysis

When specifying a static mixer, there is a lot of hype by nearly all of the manufacturers claiming high mixing efficiencies 3-10 pipe diameters down from the outlet of the mixer. These high mixing efficiencies are at best under optimum conditions and do not always translate to actual installations.

Finding the actual effectiveness of a static mixer requires sampling across the cross-sectional area of the mixer and comparing the concentrations of the chemical that is being mixed in each sample. For many industrial processes, a 5% variation in concentration is considered mixed.

There are number of challenges in accomplishing this task:

- The process of testing is very time consuming, requiring specialized equipment, such as dosing pumps, modification of the process piping and can have errors due to the accuracy of the measuring apparatus.

- Ideally the sampling should be taken all at the same instance. When sampling turbulent flow, a particular point in the cross-section can vary in concentration over the course of a few minutes.

- Using a tracer chemical that can easily be measured (radioactive, dye, or chemical) can be unacceptable to use in a potable water supply, or only very small quantities can be added.

For those who are brave enough to continue with this testing we have included a description of the most common analysis, Coefficient of Variation [CoV or C_v].

Often this testing is conducted with a tracer/benign chemical such as mixing in a salt solution or using a low concentration (ppm) of chlorine. Measuring these low concentrations accurately enough for an operator to detect a less than 5% variation requires a highly accurate testing protocol.

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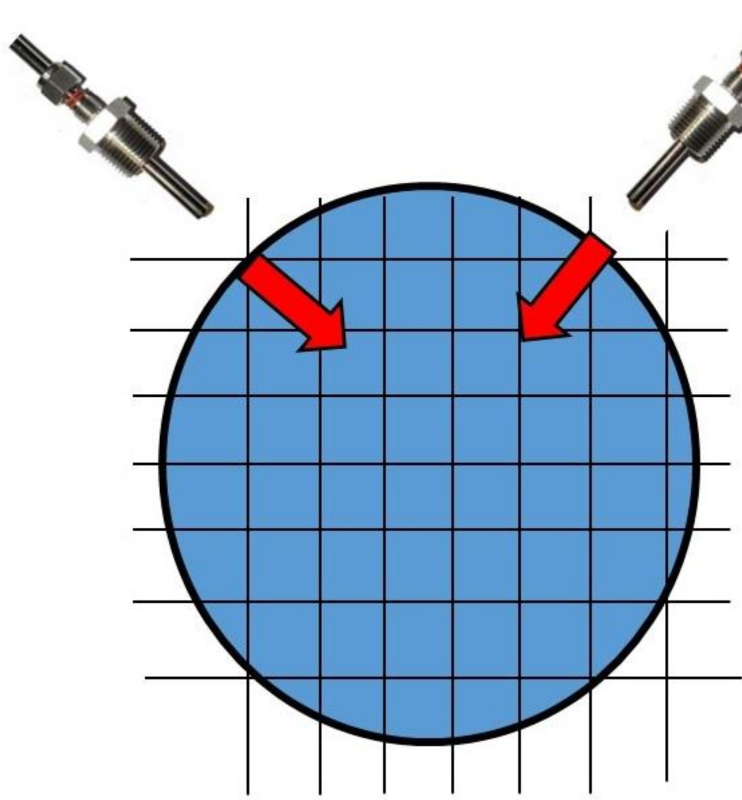
Testing Protocol
A tube used through several compression fitting type fittings and extended to a series of grid points on the cross-section of the pipeline. A sample is drawn off using a valve and flexible tubing attached to the tube, and each sample is tested and compared to samples taken at other parts of the pipeline cross-section.



Coefficient of Variation

The coefficient of variation (c_v) is a common measure of determining mixing. It is typically a percentage [often 0.05 for industrial mixing] and expressed as

$$c_v = \frac{\sigma}{\mu}$$

Where σ = standard deviation and μ = mean

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Or can be written

CoV = $\dfrac{\text{Sample Standard Deviation}}{\text{Mean}}$

Or

CoV = $\dfrac{S}{\bar{x}}$

EXAMPLE:
Find the coefficient of variation for a pipeline with a chlorine residual of 3,7,2,5,6 ppm at 5 different points in the cross-section of the pipeline

Solution:

Formula for mean:

$$\bar{x} = \frac{\sum x}{n}$$

$$\bar{x} = \frac{23}{5} = 4.6$$

Construct the following table:

x	$\bar{x} - x$	$(\bar{x} - x)^2$
3	1.6	2.56
7	-2.4	5.76
2	2.6	6.76
5	-0.4	0.16
6	-1.4	1.96
$\sum x = 23$		$\sum(\bar{x} - x)^2 = 17.2$

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Formula for sample standard deviation (*S*):

$$S = \sqrt{\frac{\sum(\bar{x} - x)^2}{n-1}}$$

$$S = \sqrt{\frac{17.2}{4}} = 2.08$$

CoV = Sample Standard Deviation / Mean

Or

$$CoV = \frac{S}{\bar{x}}$$

=2.08 / 4.6

CoV=0.45 or 45% variation

As you can see with a typical chlorine residual, the variation can be quite large with minor errors in measurement and mixing compounding to result in a large CoV. Particularly one outlying value can greatly change the CoV.