

## **CFD ANALYSIS, UNIFORMITY, COV, AND MASS TRANSFER EFFICIENCY**

This technical bulletin outlines the distinctions between Computational Fluid Dynamics (CFD) analysis of multiphase flow uniformity and its relationship to prediction of mass transfer efficiency (MTE) in sidestream gas-liquid applications utilizing both a venturi injector and a secondary mixing device, e.g. a Pipeline Flash Reactor (PFR) or Basin Nozzle Manifold (BNM).

Mazzei will often extend a mass transfer guarantee, contingent upon various site conditions such as feed gas concentration and applied mainline gas dose. In order to extend this guarantee, Mazzei frequently performs advanced multiphase flow modeling of the relevant infrastructure, including the gas-liquid contactor, secondary mixing device, and immediately adjacent inlet and outlet piping. The result of this analysis is a highly accurate prediction of mixing and homogeneity of the treated water at various planes downstream of the secondary mixing device, quantified as a uniformity index (UI), where a UI value of 1.0 represents a theoretical state of complete mathematical homogeneity. UI, while similar to the coefficient of variation (CoV), is a more reliable indicator of flow uniformity because it captures localized variations of the gas-phase volume fraction across the cross-section and weights them by the area they represent, whereas CoV reflects only the overall statistical variation about a single average value taken over the entire cross-section. The area-weighted UI of the gas phase is calculated using the following equation:

$$UI = 1 - \frac{\sum_{i=1}^n [(|\phi_i - \bar{\phi}_a|) A_i]}{2|\bar{\phi}_a| \sum_{i=1}^n A_i}$$

Where  $i$  is the index used to identify each small area element of the cross-sectional plane, and  $\bar{\phi}_a$  is the average value of the gas-phase volume fraction across the entire cross-section, given as follows:

$$\bar{\phi}_a = \frac{\sum_{i=1}^n \phi_i A_i}{\sum_{i=1}^n A_i}$$

While high UI is often a critical factor in achieving efficient mass transfer and a properly functioning ozone dissolution system in general, it is not itself a direct measure of mass transfer efficiency. Direct modeling of mass transfer efficiency is not a service currently offered. Quantifying uniformity via advanced modeling techniques allows Mazzei to establish, alongside other assumptions and proprietary techniques, a conservative projection for mass transfer efficiency sufficient to extend a performance guarantee.