Cleveland Eastern Mixers
DIVISION OF
EMI INC. TECHNOLOGY GROUP

www.emimixers.com

Static Mixer – Principles of Operation

Introduction

The Cleveland static mixer is a new design from the EMI Mixing Technology group. It is a shape that has been optimized for mixing performance and rapid and reproducible production. Engineers now have an efficient, price competitive device that can be applied in many process duties. In maximizing the benefits of motionless mixers, computerized manufacturing techniques have been utilized.

The unit will completely blend, disperse or react two or more fluids in short lengths of piping. To achieve these results, the mixer relies on the principles of radial momentum transfer, flow division and shear plane reversal. These transport phenomena combine to eliminate concentration, velocity and thermal gradients.

While many geometrical shapes have been used to create homogenous flow, the degree of energy and mixing efficiency has been inadequately addressed. By using an elliptical shape, smooth transitions are possible and no energy is wasted in back-mixing. Triangular risers are used to connect the angled elliptical shapes to prevent eddy dissipation at the element edges and further energy loss.

The elements are made in two patterns. The left-handed inclined ellipse (LH) provides clockwise rotational flow. The right-handed inclined ellipse (RH) provides counter-clockwise rotational flow. The elements are connected at 90° angles to each other, and furthermore, the two element patterns are alternated in series (i.e.; RH, LH, RH, LH...). This arrangement assures mathematically predictable results.

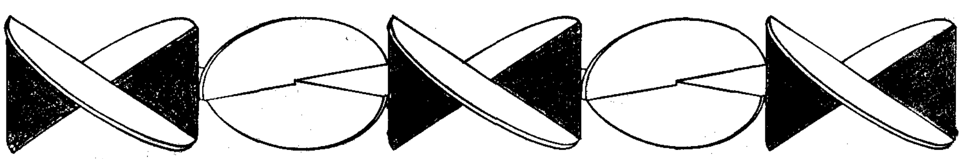


Figure 1

Transport Phenomena

Since static mixers operate in a pipeline, it is necessary to understand the inside story. Fluids proceed axially through the line in a flow regime defined by the degree of turbulence. Turbulence is characterized by the dimensionless, Reynolds Number. It specifies the ratio of inertial forces to viscous forces as follows:

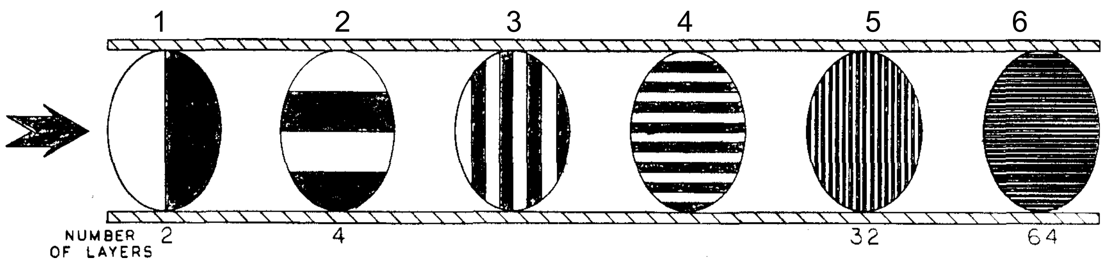
$$Nre = \frac{3157\ (s.g.)\ (Q)}{(M)\ (d)}$$

Laminar flow is defined as having no turbulence, i.e. Nre < 500, Transitional flow as 500 < Nre > 2000 and fully developed turbulent flow as Nre >2000.

The three mixing actions work independently or together. Depending on the flow regime present, they create the complete mixture desired. In addition, pipeline velocity plays an important role in the degree of uniformity achieved due to its influence on shear, and thus mass transfer.

Flow Division

When in laminar flow, two or more fluids will remain adjacent to each other indefinitely unless disrupted. By inserting mixing elements, the fluids are divided and reoriented 180° before the next element. This process proceeds geometrically to produce fluid layers of fine proportions that insure complete mixing. (see figure 2)



FLOW DIVISION
Figure 2

The number of layers can be determined as follows:

Equation 2 $NL = 2^n$

Where NL = Number of layers
X = Number of elements

Equation 3 $LT = d/NL$

Where LT = Layer thickness (inches)
D = Pipe I.D. (inches)
NL = Number of Layers

Radial Momentum Transfer

As fluid encounters the ellipse in transitional or turbulent flow, it begins to rotate in a helical pattern. Micro-shear at the film boundary is caused by frictional resistance from the elements and pipe wall. Momentum is transferred to adjacent film layers. The directional components of the momentum correspond to the shape of the resistance, i.e. the element.

This fluid layer momentum transfer continuously forces material to rotate about its hydraulic center. Mass at the pipe wall and the element centerline transfer positions constantly effect homogeneity. This momentum transfer in the radial plane eliminates the parabolic velocity profile normally seen in open pipe flow (see Figure 3). This action now approximates true plug flow, and is desirable for reactor performance since all fluid elements are undergoing a chemical reaction for equal residence times. Conversions of reactant to product are more uniform and equal.

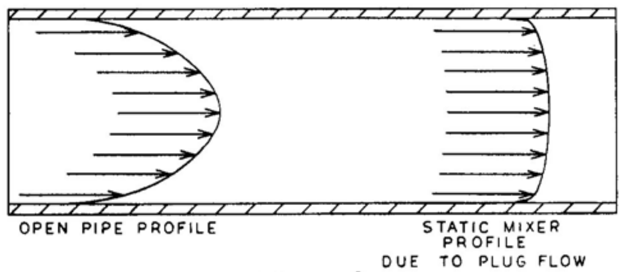


Figure 3

Inertia Reversal

Throughout the and fully turbulent flow zones, fluids encounter a dramatic directional change at the inter element connection. As the elements change from left-hand to right-hand orientation, the rapid reversal at the interface enhances the mixing effect. Here, two opposite forces of inertia come into play.

Synopsis

Knowing the basic transport phenomena involved in pipeline flow leads to an understanding of static mixing principles. To apply this basic understanding in more detail another technical report has been provided. Ask for CSM-2 SIZING AND DESIGN OF STATIC MIXERS.