stamixco

# Static Mixing, Reaction, Heat Transfer & Fluid Dynamics Technology

…equipment with no moving parts for the continuous processing of polymers, liquids gases and solids

***General Brochure Note:***

*The purpose of this brochure is to introduce our broad range of static mixer designs, describe the process unit operations that can benefit from static mixing technology and rank each of our products for their suitability in specific applications. In depth technical and design calculation information is not included in this brochure but is available upon request in our Product and Technology bulletins.*

*Also presented in this brochure are our capabilities to evaluate complex mixing and flow/pressure/velocity related issues in process equipment via Computational Fluid Dynamics (CFD) computer modeling and pilot plant testing.*


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# Introduction

For more than 40 years, static mixers (also known as motionless mixers) have been successfully used for the mixing/dispersing, reaction and heating/cooling of high and low viscosity liquids, slurries, solids, gases and the multi-phase contacting of gases, solids and liquids. They are capable of mixing materials with equal or very different viscosities and volumetric flow rates. The static mixer design best suited for a specific application is based on the process unit operation being practiced.

As shown in Figure #1, static mixers are used in continuous processes where they homogenize fluids with no moving parts. Pumps or blowers are used to deliver the components to be mixed at the desired volumetric flow rates and to also supply the pressure energy required for mixing. Typical sizes of static mixers range from very small laboratory size units that fit into 3/16" diameter tubing, process piping that ranges from 1/4" Sch. 40 to over 120"-diameter and square/rectangular ducting such as 46-feet by 13-feet for power plant flue gas treatment. As shown in Figure #2, a static mixer consists of individual mixing elements stacked in series. Each mixing element is oriented 90$^{o}$ relative to the adjacent mixing element to create mixing in both the horizontal and vertical directions. The static mixing elements divide and recombine the feed materials so that the stream exiting the static mixer is homogeneous with regard to concentration, temperature and velocity which are equalized throughout the entire pipe cross-section.

The number of mixing elements required for a specific application is a function of the customer's process and system requirements with consideration for the desired homogeneity (CoV), pressure drop limitations and fluid properties such as flow rates, viscosities, densities, etc.

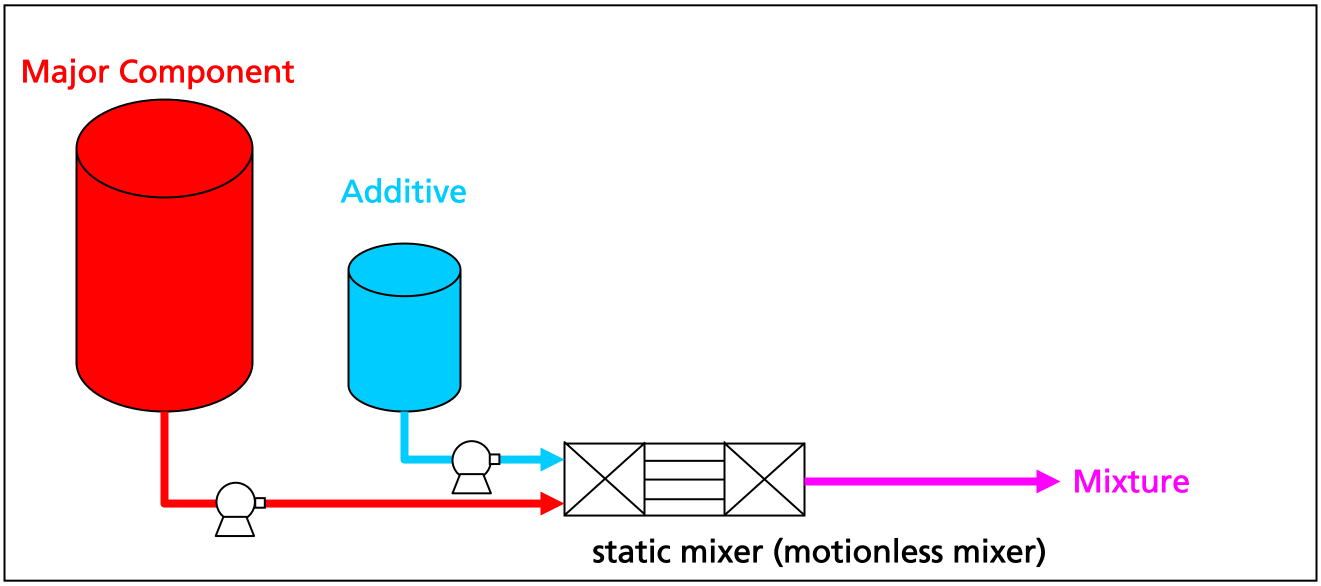



***Figure #1***: In continuous processes, static mixers create a homogeneous mix in a short length with no moving parts.

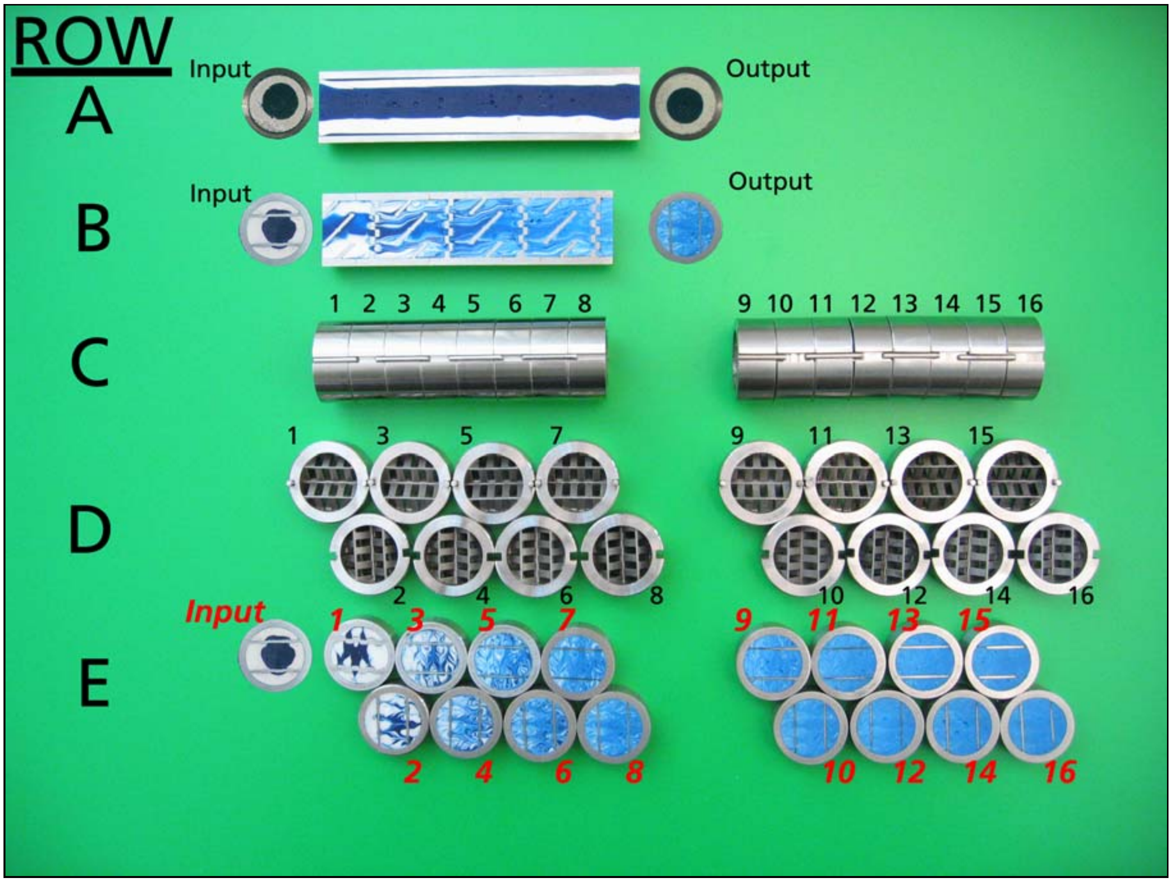



***Figure #2:*** *Mixing of Blue and White resins (1:1 volumetric ratio) is demonstrated where the blue resin is injected into the center of the tube*

- *Row A: In an empty pipe, a slice along the tube length reveals that no mixing occurs when processing viscous materials.*
- *Row B: With eight (8) Type GXR mixing elements, a high degree of mixing is achieved in a short length of L/D=~4.*
- *Row C: Two sets of eight (8) GXR mixing element assemblies are shown for a total mixer length of L/D=8.*
- *Row D: Face view of GXR mixing elements shown in Row C. Notice each mixing element is oriented $90^o$ relative to the adjacent.*
- *Row E: The degree of mixing achieved at the outlet of each mixing element shown in Rows C and D is shown in Row E.*

## Unit Operations

A wide variety of unit operations take advantage of static mixing technology including:

**Mixing/Blending:**

- Viscous Polymers, Plastics & Resins
- Liquids with large differences in Viscosity
- Low Viscosity Liquids Soluble in each other
- Gases

**Mass Transfer between Immiscible Phases**

- Gas-Liquid Contacting
- Immiscible Liquid Dispersion
- Solids-Gas & Solids-Liquid Contacting

**Heat Transfer in Viscous Material Processing**

- Heating/Cooling Viscous materials

**Reactors**

- Creating Plug Flow Reaction Conditions
- Simultaneous Plug Flow Reaction; Mixing; Heating/Cooling; and Homogenization of Concentration, Temperature and Velocity.

## Industries

Most fluid processing industries use static mixers including the following:

Polymer & Resin Production
Plastics Injection Molding & Extrusion
Chemicals
Petrochemicals
Oil Refining
Natural Gas Processing
Food Processing
Pharmaceuticals
Pulp & Paper Processing
Cosmetics & Detergents
Potable Water Treatment
Water & Wastewater Treatment
Power Plants
Energy
Catalyst Manufacture and Catalytic Reactors
Pollution Control
Minerals & Ore Processing
Vegetable Oil Processing
Parts Assembly (Plastic Disposable Static Mixers)

# Homogeneity Achieved with Static Mixers

In the early development of static mixing technology (1970's), vendors defined mix quality as the number of layers formed by a particular static mixer design and used this layer generation theory to compare performance. Claims of the formation of millions of layers we made which in reality could only be optically verified up to about 200 layers. In the 1980's, a tremendous amount of research was conducted which allowed for a technically correct and rational method of quantifying homogeneity. The method involved local measurement of a meaningful variable such as temperature, concentration, electrical conductivity, color, light passage, etc. After gathering the data, a statistical evaluation followed regarding the deviation of the measured variable from the mean value. This statistical standard deviation measure from the mean value is called the Coefficient of Variation (CoV) which has become the basis for determining static mixer performance.

To quantify and visualize CoV, Table #1 and Figure #3 are useful. Table #1 shows for the Type GX mixing element, the number of elements required to achieve a specific level of homogeneity as a function of the volumetric and viscosity ratio of the components to be mixed. Figure #3 shows the results of an experiment with the Type GX mixing element revealing the mix quality at the outlet of each mixing element, the corresponding CoV value and a ~100 time magnification of the same spot in the flow stream at the exit of each mixing element.

***Table #1.1**: Required Number of Type GX Mixing Elements in Laminar Flow Conditions*

| Volumetric Ratio Of Components A : B | Viscosity Ratio Of Components A:B | Pre-Mix Homogeneity CoV = 0.20 (80% Mixed) | Good Homogeneity CoV = 0.05 (95% Mixed) | Very Good Homogeneity CoV = 0.01 (99% Mixed) |
|---|---|---|---|---|
| 1 : 1 | 1 : 1 – 100 : 1 | **4** | **6 - 7** | **9 - 10** |
| 9 : 1 | 1 : 1 – 100 : 1 | **6** | **9** | **12** |
| 99 : 1 | 1 : 1 – 100 : 1 | **9** | **12** | **15** |

***Table #1.2**: As the viscosity ratio of the materials to be mixed increases, the additional number of mixing elements required to achieve the CoV noted in Table #1.1 is shown in Table #1.2 below.*

| | Viscosity Ratio A : B | | | |
|---|---|---|---|---|
| | > 100 - 300 | > 300 – 1,000 | > 1,000 – 3,000 | >3,000 – 10,000 |
| Additional Type GX Mixing Elements Required above a Viscosity Ratio of 1:1 : 100:1 | **2 - 3** | **3** | **3 - 4** | **4** |

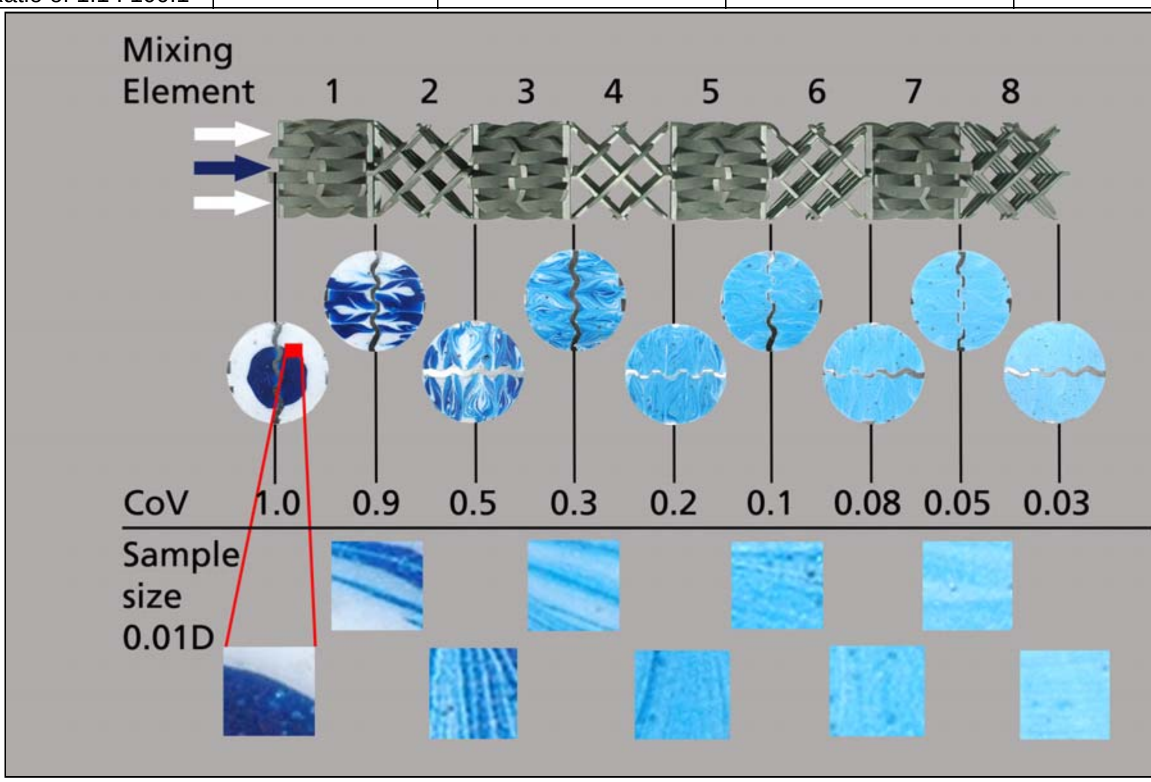



***Figure #3**: The Coefficient of Variation of mixing (CoV) for the Type GX static mixer in laminar flow is visualized in the above experiment. Blue and white viscous resin (1:1 volumetric ratio) are pumped through eight (8) static mixing elements, allowed to harden and cross-sectional cuts are made at the outlet of each mixing element. Notice how rapidly the streams are mixed. The magnified sample of 0.01D reveals that homogeneity is achieved in both the macro and micro scale.*

# Equipment Scope of Supply

Unit Operations rely on specific mechanisms to accomplish their function. There is no one piece of equipment that is best suited for all unit operations. Static mixers are no exception to this general rule.

For this reason, StaMixCo manufactures a broad range of static mixer designs of different geometric structures. This allows us to make an unbiased recommendation as to which design is best for a specific application. If our equipment is not best for your specific application, we will tell you so and recommend a supplier who can assist you.

Below is a short guide that will help you identify the proper type of static mixer for your specific application. We have taken the liberty of rating each design for the particular application based on our experience in the industry, cost, process suitability, and many other factors. Detailed Technical Literature is available for each product upon request.

**Rating System of Products**: **10**: Best-Available Technology **5**: Acceptable for the Application **0**: Not Suitable for the Application
**–**: Not Applicable ✱: Equipment size not available

## General Purpose Static Mixers

| STATIC MIXER SCOPE OF SUPPLY | | | LAMINAR FLOW (high viscosity materials) | | | | | | | TURBULENT FLOW (low viscosity materials) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHOTOGRAPH OF STATIC MIXER STRUCTURE | PRODUCT MODEL DESIGNATION<br>CHARACTERISTIC FEATURE OF STATIC MIXER DESIGN | DIAMETER OF STATIC MIXER | Extrusion | Injection Molding | Similar Viscosity Mixing | High – Low Viscosity Mixing | Large Volumetric Ratio of Materials | Heating – Cooling | Plug Flow Reactors | Liquids Blending | Low – High Viscosity Mixing | Immiscible Liquids Dispersion | Gas Mixing | Gas-Liquid Contacting | Solid-Gas Contacting | Solid – Liquid Contacting |
|  | **Type H**<br>Helical Twist of 180° with adjacent Mixing Elements of Opposite Twist | **< 1”** | 5 | 0 | 5 | 0 | 2 | 10 | 2 | 10 | 2 | 8 | 8 | 8 | 10 | 10 |
| | | **1”–6”** | 3 | 0 | 4 | 0 | 1 | 3 | 0 | 8 | 0 | 6 | 6 | 6 | 6 | 6 |
| | | **6”–18”** | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 6 | 0 | 5 | 5 | 3 | 0 | 0 |
| | | **> 18”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 2 | 1 | 0 | 0 |
|  | **Type V**<br>Corrugated Plates at 45° or 30° to pipe axis with adjacent Mixing Elements at 90° | **< 1”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 8 | 10 | 6 | 6 | 0 | 0 |
| | | **1”–6”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 6 | 10 | 10 | 10 | 6 | 2 |
| | | **6”–18”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 6 | 10 | 10 | 10 | 6 | 5 |
| | | **> 18”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 6 | 10 | 10 | 10 | 6 | 6 |
|  | **Type GXR**<br>Double Roof Disk with 45°Crossing-Bar Grid Structure and very high strength | **< 1”** | 10 | 10 | 8 | 6 | 6 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **1”–6”** | 10 | 10 | 8 | 6 | 6 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **6”–18”** | 10 | - | 8 | 6 | 6 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **> 18”** | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
|  | **Type GX**<br>Crossing-Bar Grid Structure at 45° to pipe axis | **< 1”** | 4 | 3 | 10 | 10 | 10 | 5 | 10 | 5 | 5 | 3 | 0 | 0 | 0 | 0 |
| | | **1”–6”** | 6 | 4 | 10 | 10 | 10 | 10 | 10 | 6 | 6 | 4 | 4 | 3 | 4 | 4 |
| | | **6”–18”** | 7 | 0 | 10 | 10 | 10 | 2 | 10 | 7 | 7 | 4 | 9 | 4 | 6 | 6 |
| | | **> 18”** | 10 | - | 10 | 10 | 10 | 0 | 10 | 8 | 8 | 5 | 10 | 8 | 10 | 10 |
|  | **Type GX-L**<br>Crossing Bar Grid Structure at 30° to pipe axis | **< 1”** | 0 | 0 | 5 | 0 | 4 | 8 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **1”–6”** | 0 | 0 | 4 | 0 | 3 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **6”–18”** | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **> 18”** | 0 | * | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | **Type GX-LR**<br>Crossing Bar Grid Structure at 30° to pipe axis with each ellipse at 90°. | **< 1”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | **1”–6”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 5 | 0 | 5 | 5 |
| | | **6”–18”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 4 | 0 | 4 | 4 |
| | | **> 18”** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 3 | 0 | 3 | 3 |

## Heat Exchangers

| | | |
|---|---|---|
|  | Monotube Heat Exchangers | • Consists of a single pipe with mixing elements and a jacket for Heating/Cooling fluid (or heating tape wrapped on pipe surface).<br>• Six-fold increase in heat transfer as compared to an empty pipe when processing viscous materials<br>• Generally Cost & Process Effective in sizes 6-inch diameter and smaller<br>• Simultaneously Provides<br>o Heat Transfer (cooling or heating)<br>o Mixing/Dispersion<br>o Uniform Residence Time Distribution (function of mixer geometry)<br>o Mixing/Reaction/Heat Transfer in long lengths with low pressure drop. |
|  | Multitube Heat Exchangers | • Consists of many tubes in parallel with mixing elements inside each tube. Mounting can be in any conventional Multitube heat exchanger configuration.<br>• Six-fold increase in heat transfer as compared to an empty pipe when processing viscous materials<br>• Generally Cost & Process Effective in any size and can handle very large process flow rates and heating-cooling duties.<br>• Simultaneously Provides<br>o Heat Transfer (cooling or heating)<br>o Mixing/Dispersion<br>o Uniform Residence Time Distribution (function of mixer geometry) |

## Plastic Disposable Static Mixers

| | | |
|---|---|---|
|  | **Type H-P**<br>Plastic Disposable Helical Twist of 180$^o$ with adjacent Mixing Elements of Opposite Twist | • Helical type design are the most cost effective plastic disposable mixer<br>• Excellent for simple-to-medium difficulty applications when processing materials with similar viscosity and volumetric ratios of 1:1 up to 5:1.<br>• Available in many diameters up to 1-inch, with 8 – 60 mixing elements in each unit and with a wide variety of connections, tips and accessories. |
|  | **Type GXF**<br>Plastic Disposable Double Roof Disk with 45$^o$Crossing-Bar Grid Structure Edge Sealed To Disk Wall | • Cost effective for difficult mixing applications that cannot be handled by the industry standard Type H-P plastic disposable Helical static mixer design.<br>• Very short length as compared to helical mixers.<br>• Ideal for difficult mixing applications such as materials with large differences in viscosity and volumetric ratio and very low viscosity materials.<br>• Available at present in a 10 mm mixing element diameter with 6, 9 and 12 mixing elements in a housing with bell connection and stepped tip.<br>• Available in a high pressure metal housing with any end connections |
|  | **Type GX-P**<br>Plastic Disposable Crossing-Bar Grid Structure at 45$^o$ to pipe axis with very high strength | • Cost effective for very difficult mixing applications that cannot be handled by the industry standard Type H-P Helical static mixer design.<br>• Very short length as compared to helical mixers.<br>• Ideal for difficult mixing applications such as materials with large differences in viscosity and volumetric ratio and very low viscosity materials.<br>• Available at present in a 10 mm mixing element diameter with any number of mixing elements in a plastic housing with bell connection and stepped or luer tip.<br>• Available in high pressure metal housing with any end connections |
|  | **Type GXR-P**<br>Double Roof Disk with 45$^o$Crossing-Bar Grid Structure Edge Sealed To Disk Wall and with very high strength | • Cost effective for very difficult mixing applications in large throughputs that cannot be handled by the industry standard Type H-P Helical static mixer design.<br>• Very short length as compared to helical mixers.<br>• Ideal for difficult mixing applications such as materials with large differences in viscosity and volumetric ratio and very low viscosity materials.<br>• Available at present in a 21 mm mixing element diameter in a high pressure metal housing with any end connections |

# Computational Fluid Dynamics (CFD) Computer Modeling Technology

## *For Optimizing Mixing, Velocity, Pressure and Temperature Profiles in Process Equipment*

In the continuous processing of polymers, liquids, gases and solids, it is often necessary to mix, react, disperse, heat/cool and condition flow for further processing in downstream equipment. Static mixers, in combination with injectors and flow conditioning devices such as turning vanes, flow rectifying grids, etc., are used extensively to optimize performance in process equipment. Sizes range from as small as 1/16-inch diameter tubing to round, square and rectangular vessels up to 50-feet x 30-feet and larger cross section.

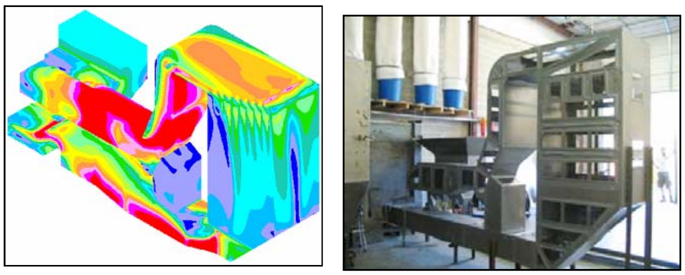


***Figure 11.1**: CFD Model (left) and 1:12 scale pilot plant physical flow model (right) to verify CFD results. Vessel includes static mixers, ammonia injectors, turning vanes and rectifying grids to optimize mixing and temperature/velocity/pressure profiles at catalyst face for a 350 MW SCR (DeNO$_x$) plant (photos courtesy of FlowTech AG, Winterthur, Switzerland; www.flowte.ch).*

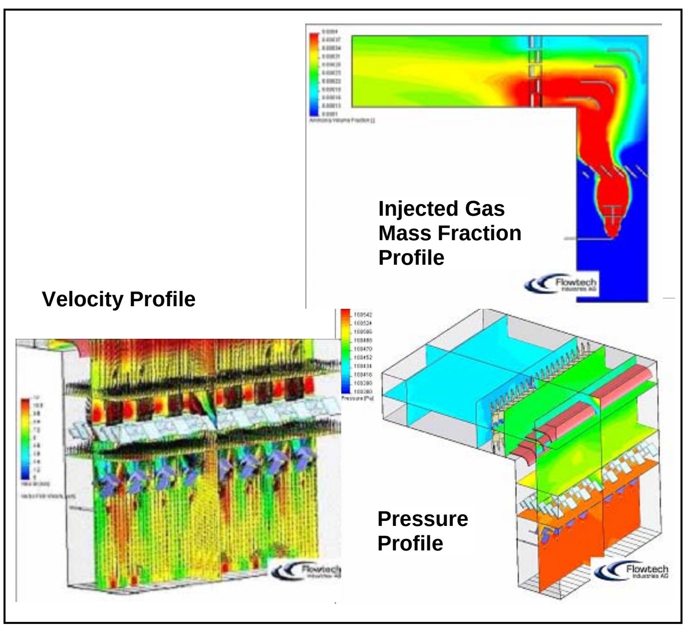



***Figure #11.2**: CFD of Commercialized Tail End SCR (DeNO$_x$) unit with static mixers, ammonia injectors, turning vanes and rectifying grids to optimize mixing, thermal homogenization and velocity/pressure profiles at catalyst face (photos courtesy of FlowTech AG, Winterthur, Switzerland; www.flowte.ch).*

StaMixCo, in association with our CFD technology partner, FlowTech AG of Winterthur, Switzerland (www.flowte.ch), provide CFD computer modeling to design and optimize process equipment as well as to build and test pilot plant size physical flow models to verify CFD results. With over 150 large commercial installations, you are assured of an experienced and professional team to analyze and solve your process equipment optimization requirements.

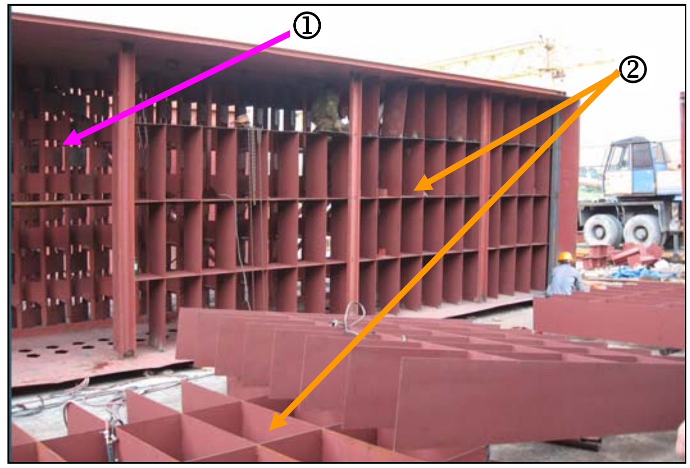



***Figure #11.3:** Rectangular cross-section (46-feet by 13-feet) X-Grid Static mixer (1) and Rectifying Grid (2) to optimize mixing of injected ammonia and temperature/velocity/pressure profile at catalyst face for a 660 MW SCR (DeNo$_x$) plant on a Coal Fired Power Plant (Photos courtesy of FlowTech AG, Winterthur, Switzerland; www.flowte.ch).*

Unit Operations, Processes and Industries that benefit from the combination of Static Mixing, Flow Conditioning and CFD Technology include the following:

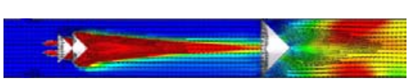
**<u>Chemical Processing & Oil Refining Industries</u>**

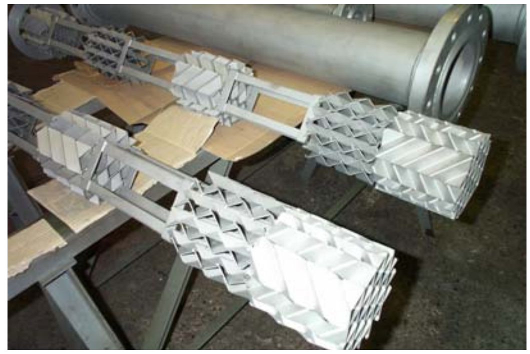
• *<u>Catalytic Reactors</u>*: Many processes use low pressure drop catalysts such as platinum gauze, honeycomb monolith, and radial flow catalyst beds. In order to maximize yield and catalyst life, it is necessary that the feed stock entering the catalyst be well mixed and exhibits a flat velocity, pressure and temperature profile. Examples of processes with these requirements include Nitric Acid, Hydrogen Cyanide, Ethylbenzene dehydrogenation.

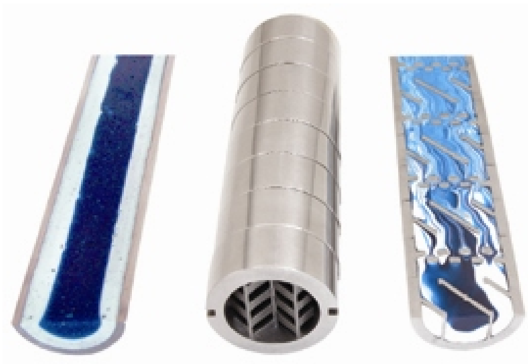
• *<u>Empty Process Vessels or with Low Pressure Drop Internals</u>*
The performance of empty process vessels and equipment with low pressure drop internals can often be dramatically improved by correcting highly skewed velocity, pressure and flow profiles directly attributable to vessel internals, entry and exit conditions. CFD analysis of existing equipment configurations pinpoint areas of concern, allow for strategic customer field measurements to verify CFD results (or physical flow modelling) that normally results in a simple and cost effective fix. Examples of process equipment with these issues include Spray Towers, Scrubbers, Absorbers, Strippers, Distillation Columns, Air Heaters, Heat Exchangers, Duct Burners, Baghouses and Electrostatic Precipitators.

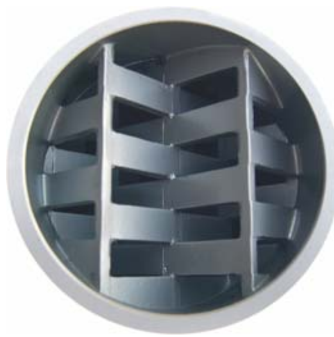
**<u>Power Generation Industry</u>**

Over 100 commercial size projects have been executed for the Power Generation Industry involving SCR/DeNOx abatement plants with liquid ammonia pre-vaporization and injection through a grid; $SO_3$ abatement plants with Magnesium Oxide powder injection, High Coal Dust SCR plants, Wet FGD Gas-Liquid plants (2-phase flow), Power Plant Optimization, Diesel Engines, Gas Turbines, Bag Houses, Electrostatic Precipitators, Air Heaters, etc.









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**A young company with over 50 years of employee accumulated experience in mixing technology.**


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