DESIGN GUIDELINES FOR STATIC MIXING UNITS

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Static mixing units are now being used to solve a widening variety of mixing problems. The sophistication of static mixers has grown with the increasing complexity of applications. There are now several different mixer designs to choose from when designing a static mixer. The most efficient design depends upon the particular mixing problem being solved.

PRINCIPLE OF OPERATION

Static mixing units, also referred to as in-line mixers or motionless mixers, utilize the energy of the flowing fluid to create a series of divisions and recombinations within the mixer. The continuous mixing in the flow channels throughout the length of the mixer results in a homogeneous product at the mixer outlet.

FUNDAMENTALS OF FLUID FLOW

Among the numerous flow regimes possible in a flowing fluid there are three that predominantly recur in static mixing systems:

1) Mixing of Miscible Components in Turbulent Flow
2) Mixing of Immiscible Components in Turbulent Flow
3) Mixing in Laminar Flow

The primary purpose of this design guide is to address the mixing of two or more miscible fluids in turbulent flow. Immiscible fluid mixing and laminar mixing are significantly more complex and should be addressed individually by a mixing specialist.

Turbulent Flow Systems

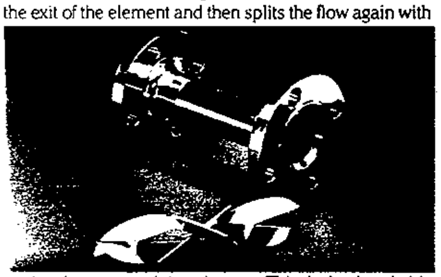
Turbulent flow can generally be considered to occur in a static mixer at empty pipe Reynolds numbers above 2000. Most fluids with a viscosity less than approximately 100 centipoise will flow in the turbulent regime at velocities above 0.5 ft/sec. Once turbulent flow has developed in a flowing stream there is a very minor gain in efficiency achieved by increasing the velocity in the mixer. A well designed static mixing unit will utilize the turbulence present in the fluids to create a very homogeneous mixture in a short pipe length.

MIXER DESIGN OPTIONS

There are four primary static mixing designs available:

Two Channel Mixer (SMXL-B™)

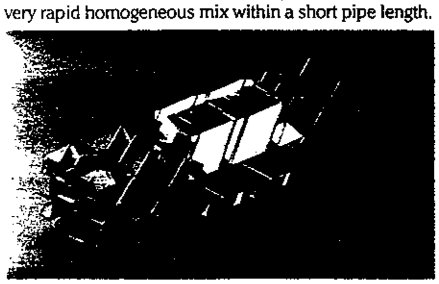
This mixer design divides the incoming flow into two channels in the first mixing element, recombines them at the exit of the element and then splits the flow again with



each subsequent mixing element. This design is suitable for mixing of two miscible components in turbulent flow, particularly where a high mixing efficiency is not required.

Corrugated Plate Mixer (SMV™)

This mixer design divides the incoming flow into several channels within each mixing element creating a very rapid homogeneous mix within a short pipe length.



This design is well suited for the mixing of non-plugging miscible fluids in turbulent flow, gas-gas mixing, and is particularly well suited for gas-liquid contacting and for contacting immiscible fluids – especially when the goal is to achieve a high mass transfer or extraction efficiency.

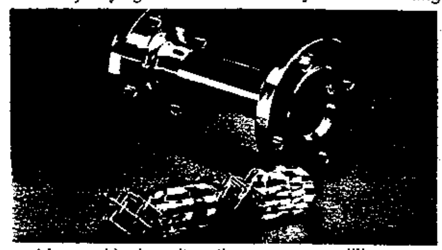
Non-Fouling Three-Channel Mixer (SMF™)

This open design drives the incoming flow away from the pipe wall and back into the middle of the pipe within each element. Independent testing has shown this

design to provide a high mixing efficiency at a minimal pressure drop. This design is well suited for all miscible fluid applications, especially when there is a high degree of solids or fibrous material present and a tendency to foul or plug.

Multiple Cross-Bar Mixer (SMX™)

This design was developed specifically for the mixing of fluids in laminar flow. The cross-bar design provides intimate mixing of components having high viscosities or widely varying viscosities. Previously unsolved mixing



problems with viscosity ratios up to one-million-to-one have been easily handled with this design. The SMX design also promotes the radial mixing required for plug flow reactors and for heat transfer enhancement in viscous systems.

MIXING OF MISCIBLE COMPONENTS IN TURBULENT FLOW

The chart below can be used as an aid in selecting the number of mixing elements for a particular application. As the flow ratio of the lesser component is decreased, the mixing task increases in difficulty. The SMXL-B™, a two-bladed open design, will require more mixing elements than the high efficiency design of the SMV™ or SMF™.

MIXING OF MISCIBLE COMPONENTS IN TURBULENT FLOW

ADDITIVE FLOW RATIO (MINOR COMPONENT FLOW/TOTAL FLOW)	SMV™ OR SMF™ # ELEMENTS	SMXL-B™ #ELEMENTS
ABOVE 10%	2 ELEMENTS	3 ELEMENTS
0.1 TO 10%	3 ELEMENTS	4 ELEMENTS
LESS THAN 1,000 PPM (0.1%)	4 ELEMENTS	6 ELEMENTS

MIXING ELEMENT SELECTION CRITERIA

SMVL: For high efficiency, low pressure drop mixing applications. Used for mixing miscible components in a short pipe length. Also used occasionally for high/low viscosity blending. Standard design for most general turbulent flow applications.

SMV™: For high efficiency, high shear mixing applications. Used primarily for two phase contacting such as absorption of a gas into a liquid or dispersion of two liquid phases.

SMF™: For high fiber content and sludge streams. Designed to pass long fibers and large solids while maintaining high mixing efficiency.

SMXL-B™: For lower viscosity, pluggage prone mixing applications. Will handle solids loading and minor amounts of fibrous material. Used for processes requiring a more open design and/or lower shear rate.

PRESSURE DROP PER ELEMENT FOR LOW VISCOSITY LIQUIDS IN TURBULENT FLOW

SMVL	(30° SMV™, L/D = 1)	Δ P/Element = $.0020 \times Q^2/D^4 \times (S.G.) \times (VIS)^{.05}$
SMV™	(45° SMV, L/D = 1)	Δ P/Element = $.0045 \times Q^2/D^4 \times (S.G.) \times (VIS)^{.05}$
SMF™	(Non-Impinging, L/D = 1)	Δ P/Element = $.0020 \times Q^2/D^4 \times (S.G.) \times (VIS)^{.05}$
SMXL-B™	(Dual-Blade, L/D = 1.4)	Δ P/Element = $.0015 \times Q^2/D^4 \times (S.G.) \times (VIS)^{.05}$

NOMENCLATURE: Δ P - PRESSURE DROP IN PSI
Q - FLOW RATE IN GPM
D - INSIDE DIAMETER IN INCHES
S.G. - SPECIFIC GRAVITY (S.G. = 1 FOR WATER)
VIS - VISCOSITY IN CENTIPOISE (VIS = 1 CP FOR WATER)