Static Mixer Designs and Applications

A White Paper Prepared By

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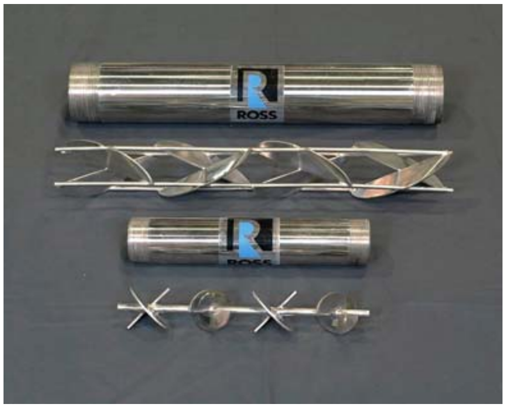
Abstract

Originally developed for niche markets, static mixers today serve a broader user base and have become more widespread throughout the process industries. Their high performance, low operating and maintenance cost, durability and continuous operation make them very appealing tools for improving mixing, emulsification, reaction and heat transfer.

For many decades, Ross has supplied static mixers for various installations, from refineries and pipelines to wastewater treatment plants and manufacturing facilities of chemicals, food, plastics, composites, adhesives, pharmaceuticals, ceramics, etc.

The aim of this paper is to provide practical information on the specification and use of Ross Static Mixers. Sample applications and mixer selection tips are also presented.

Introduction



A static mixer or motionless mixer is a device inserted into a housing or pipeline with the objective of manipulating fluid streams to divide, recombine, accelerate/decelerate, spread, swirl or form layers as they pass through the mixer. As a result of these alterations in the fluid flow, mixture components are brought into intimate contact. Static mixers are therefore utilized not only for strictly mixing requirements but also reaction processes. Flow in an empty pipe produces some degree of radial mixing but in most cases, adequate mixing can only be achieved by an impractical length of pipe. Inserting a static mixer significantly accelerates inline mixing or reaction. This technique is essentially desirable wherever a continuous, inexpensive and fast operation is required. Since there are no moving parts in the motionless mixer, it is basically maintenance-free and can be installed as easily as any piece of pipe.

Energy for mixing is available in the form of pressure. Whether material is gravity-fed or forced through the mixer using external pumps, pressure loss is one consequence of static mixing and is sometimes the limiting factor in mixer selection.

There are several types of motionless mixers to select from depending on the particular application. Some of the more typical designs consist of plates, baffles, helical elements or geometric grids positioned at precise angles to direct flow and increase turbulence. Others are composed of discrete conduits or segments that stack together to form a complete mixer. Shapes also vary - conventional static mixers have a round cross-section but other shapes are also available (square, rectangular, etc.) for specific requirements.

When designed and sized properly, static mixers provide excellent continuous mixing of single- or multi-phase applications with repeatable results. This mixing performance can be predicted based on flow rate, viscosity, density, percentage of mixture components and pipe dimensions.

The measure of uniformity or mixedness most often used is the radial variation coefficient (CoV). Imagine two individual streams, Part A and Part B, entering a static mixer in equal amounts: each component occupies two distinct areas as viewed from the cross-section of the pipe. As the materials move through each mixer element, the areas occupied by each component become more and more intermingled. The proportion of Part A and Part B stays the same at all times (1:1) but each component becomes more evenly distributed throughout the pipe's cross-section.

In an ideal situation, samples taken from any point in the cross-section immediately after the static mixer will have a concentration of 50% Part A and 50% Part B. CoV in this instance is zero, as there is no variation from the mean concentration and the mixture is completely homogenous. But in the practical sense, a radial coefficient of variation of 0.05 or less is acceptable for most processes. In other words, "95% mixing or better" is a typical target for most static mixer applications. Thus, the number of elements prescribed for a specific process is usually the minimum required to reach a 0.05 CoV. Obviously, proper dosing is important and assumed as a given.

Over the years, static mixer suppliers have developed their own models and formulas for sizing. Certain designs are marketed towards specific processes, i.e. wastewater treatment, plastics extrusion or petrochemical refining. Other models are more flexible in terms of application and have a rugged design that can handle solid-liquid, liquid-liquid, gas-liquid and even free-flowing solid-solid mixing requirements.

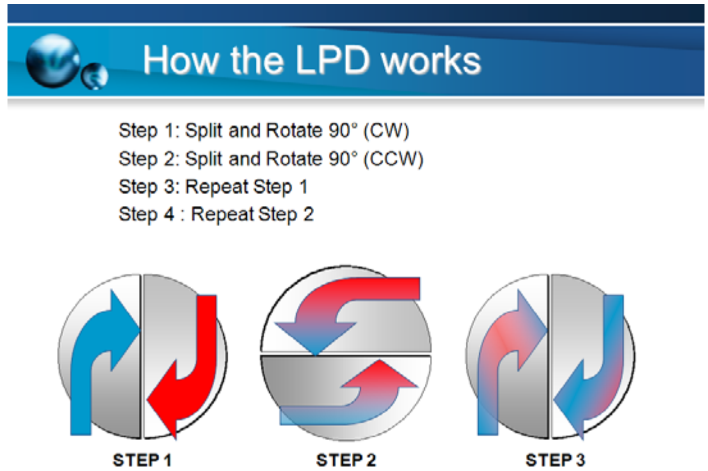
In particular, the Ross LPD/LLPD (Low Pressure Drop) and ISG (Interfacial Surface Generator) Static Mixers are well known for their wide ranging uses in turbulent and laminar flow mixing applications. Each design can be supplied as complete plug-in modules or as removable elements for installation into the end user's preferred housing design.

Low Pressure Drop Static Mixers for Turbulent Flow Processes

Since static mixers rely on external pumps to move product across the mixer elements, pressure drop often serves as a basis for selecting the appropriate static mixer. In many cases, the type and number of mixer elements are chosen so as to effect the best mixing possible without exceeding a maximum allowable pressure drop.

Ross LPD and LLPD Static Mixer Designs

An LPD Static Mixer consists of a series of semi-elliptical plates discriminately positioned in series. Two plates perpendicular to each other make up a single element. The mixing operation in this type of static mixer is based on the splitting and diverting of the input stream(s).



Top: Illustration of how the fluid stream is split and diverted while travelling through a set of LPD static mixer elements.

Bottom: A stainless steel 1″ dia. x 4-element LPD static mixer shown with a standard Schedule 40 housing with threaded ends. A thicker pipe and heavy-duty flanges can be supplied for high pressure requirements

As the product moves through each element, flow is continuously split into layers and rotated 90 degrees in alternating clockwise and counterclockwise directions. This method of subdividing the flow and generating striations results in a highly predictable and repeatable mixing strategy commonly employed for high flowrate, low viscosity applications. During turbulent flow, the mixer elements enhance the random motion of molecules and formation of eddies. Four or six LPD elements are usually sufficient for most low viscosity mixing requirements.

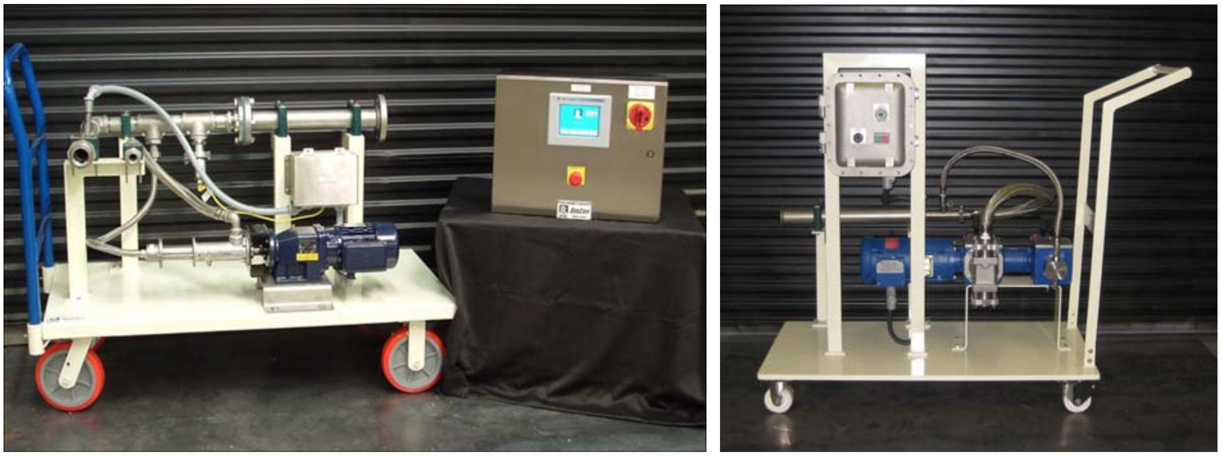
Construction

Mixer elements 1" through 2.5" diameter are welded to a central retaining rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. LPD elements are supplied as removable inserts or as a complete module with housing.

Retainers are provided to secure the elements and keep them from spinning or moving downstream. The retainer design depends on the end fittings of the mixer housing, i.e. flange, threaded, or tri-clamp connections. As an option, the mixing elements can also be welded in place.

LPD mixers are fabricated in stainless steel type 316 or 304 and in carbon steel. When mixing harsh materials that are not compatible with these materials, the elements and the inside of the housing may be coated with fluoropolymer resin (Teflon®, Tefzel®) , polyvinylidene fluoride (Kynar®), or other compatible material that can protect against corrosion or chemical attack.

Other common options include built-in injection and sampling ports, adaptors, sanitary finish, heating/cooling jacket on the housing, skid systems, controls, etc.



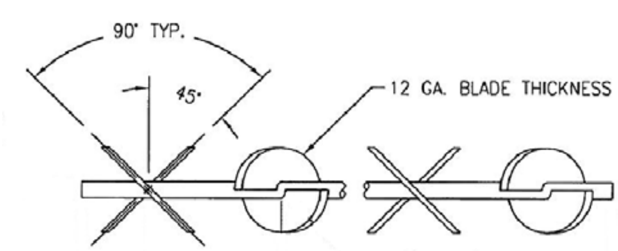
Ross Static Mixer Skid Systems complete with piping, controls, pumps and mobile skid.

Sizing

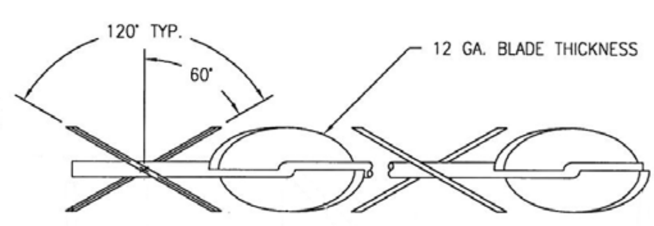
In many cases, the diameter of the static mixer is the same size as the process pipeline. The number of elements depends on the degree of mixing required which can be estimated based on flowrate, viscosity, density and percentage of the most minor component. Increasing the number of elements improves mixing efficiency but also leads to a higher pressure loss.

LPD vs. LLPD Design

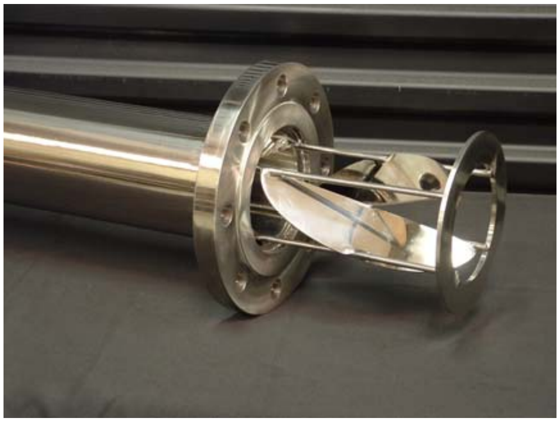
When the available pressure drop is limited, an LPD mixer with a larger diameter than the process piping can be selected. The larger mixer housing is inserted into the existing line using appropriate adaptors. Another option is to use a slightly different style static mixer. The LLPD consists of semi-elliptical plates like the LPD design, but the plates are 120 degrees relative to each other instead of 90 degrees. Length to diameter ratio increases from 1.5 to 1.75, and pressure drop is reduced by a factor of 0.46.



LPD Static Mixer



LLPD Static Mixer



A stainless steel LLPD Static Mixer in a standard housing with 150# flanges. A retainer ring is supplied on one end of the mixer. The ring is designed to be sandwiched between two flanges (that of the mixer housing and the next piece of pipe) to keep the elements from spinning or going downstream.

All wetted parts of this carbon steel LLPD static mixer are coated with a 20-25 mil thick fluoropolymer coating for corrosion resistance. An injection port is supplied on the mixer housing. This particular unit is used for continuous dilution of a hydrochloric acid solution with water at a 1:15 ratio. Both fluids are continuously metered in at 100^{o}F.

Sample Applications

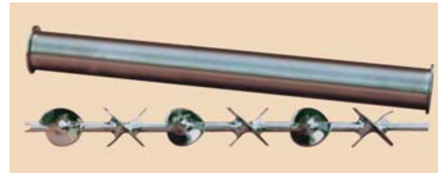
LPD and LLPD static mixers are used in many processes including:

- Blending different grades of oil or gasoline
- Mixing two or more liquid resins
- Dilution of concentrated solutions
- Water and wastewater treatment
- Gas-liquid dispersions
- Pipeline reactions
- Oil/water and water/oil emulsification
- Biodiesel production
- Blending anti-oxidants and other additives
- Chlorine dioxide bleaching of pulp
- Inline addition of flocculants
- Homogenizing process streams for sampling
- Adjusting viscosity
- Chemical suspensions
- pH control

Sanitary Applications

Food, pharmaceutical and cosmetic applications are also routinely processed in sanitary LPD and LLPD static mixers. These models are specifically designed for processing applications that require quick take-apart construction for frequently cleaning and inspection. Quick disconnect tri-clamp connections are normally provided for fast and easy removal of the elements from the sanitary tubing.

Sanitary LPD and LLPD mixers are manufactured in stainless steel 316 and have a #4 finish internally and externally. All welds are ground smooth and are free of cracks and crevices. Mirror finish is offered as an option.

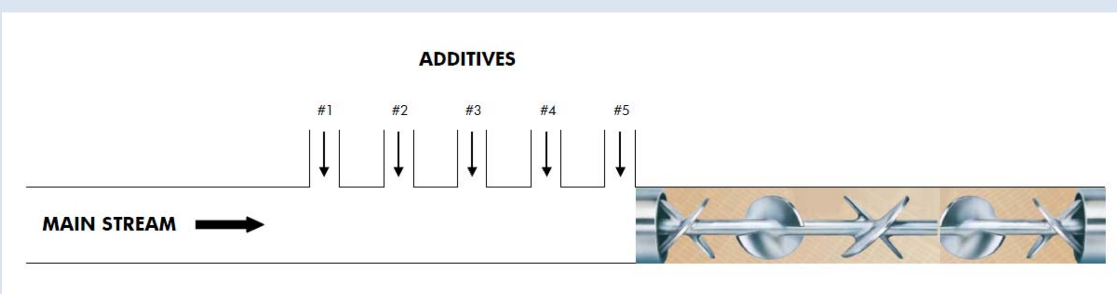


Sanitary LPD (top) and LLPD (bottom) Static Mixers.

LPD MIXER APPLICATION SNAPSHOT: FUEL BLENDING

In the manufacture of gasoline for automotive use, refineries blend in a series of streams consisting of various additives, color components and chemical compounds that enhance fuel performance. Typically, this blending operation is the final step before the gasoline leaves the refinery, thus it is important that great uniformity is accomplished.

In the past it has been assumed that turbulence induced by pumping the material across a distance equivalent to 100 pipe diameters is sufficient to produce a good mixture. Studies however have shown that some materials, due to differences in density and/or viscosity, do not actually blend into the main stream but ride along the bottom or top of the pipe en route to the tank farm. Installed in many refineries, Ross LPD (Low Pressure Drop) static mixers ensure complete mixing of all additives and gasoline in a very short run of pipe.



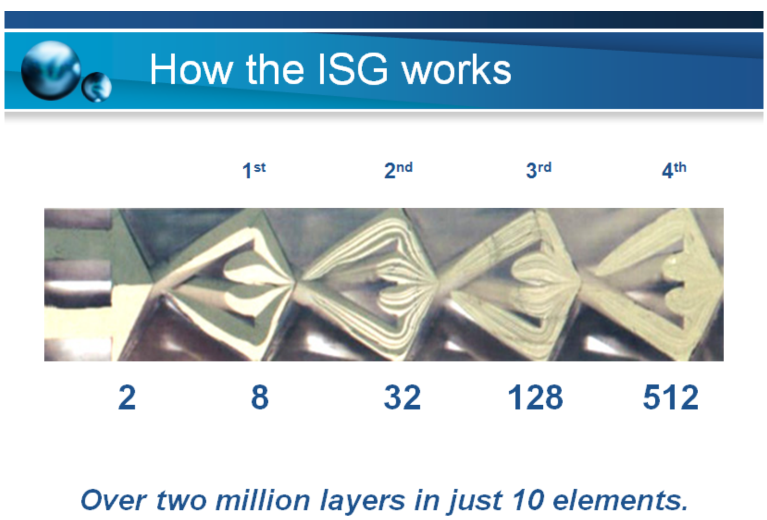
High Viscosity and Laminar Flow Processes

High viscosity and low flowrate contribute to a transition in the flow regime, from turbulent to laminar. Either variable can affect the mixing efficiency in an LPD or LLPD static mixer such that a $\leq$0.05 CoV is achieved only after numerous elements. In addition to being cost-prohibitive, the mixer would not be suitable for pipelines or process set-ups that are limited in space. In these cases, a move to a different design of static mixer is recommended in order to work with a more practical mixer length.

Ross ISG Static Mixer

The Ross Interfacial Surface Generator (ISG) is a unique motionless mixer design consisting of solid piece elements bored with four holes. The ends of the elements are precisely shaped to create a good seal and form a tetrahedral chamber between adjacent elements.

The four holes in each ISG element are at oblique angles such that material entering from the periphery (i.e. near the pipe wall) on the inlet side emerges near the center on the outlet side. If two input streams enter the ISG static mixer, the number of layers emerging from the first, second and third elements are 8, 32 and 128. This exponential progression generates over two million layers in just 10 elements.



The ISG's mixing mechanism is ideal for high viscosity and laminar flow applications with a Reynolds number below 500. Blending a minor component such as a low-viscosity dye, catalyst or additive into a viscous material is a classic ISG application. Complete mixing is achieved in an extremely short length of pipe so this type of static mixer is also utilized for turbulent flow requirements with space limitations and no maximum pressure drop.

Like the LPD and LLPD static mixers, the ISG is also suitable for sanitary processes since the elements are easily removed from the housing to be cleaned and sanitized individually.

Construction

Standard ISG elements are supplied from 5/8” to 6" diameter in stainless steel, polypropylene and Teflon. The housing can also be supplied with flange, threaded, or tri-clamp end fittings.

The ISG elements are simply stacked together and they seal automatically. Retainers on each end of the housing maintain the seal between mixer elements and prevent them from shifting around. A secure and snug fit of the elements inside the housing is critical to the performance of the ISG static mixer.

ISG Sample Applications

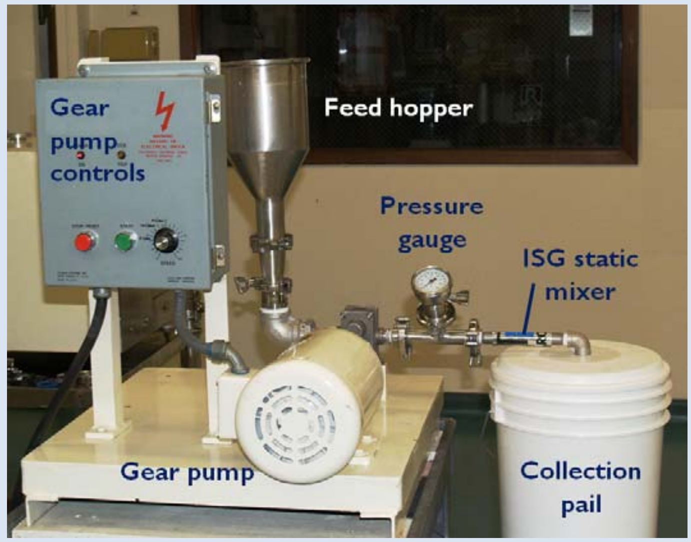
- Color blending
- Delustering of polymer dopes
- Water/fuel oil emulsions
- Blending of viscous fluids
- Injection molding and extrusion applications (mounted in the nozzle)
- Submicron emulsions
- Resin-catalyst mixtures
- Fiber-reinforced composites
- Sanitary emulsions

Left: A stainless steel ISG static mixer and a jacketed housing with 150# flanges. Right: An ISG static mixer with NPT connections and retainers.

ISG APPLICATION SNAPSHOT: COSMETIC GEL

Pilot-scale trials were performed to determine how well the Ross ISG Static Mixer can reduce droplet size for a particular viscous gel emulsion. Target droplet size: <5 microns.

The base emulsion consisting of 98% aqueous gel and 2% oil was prepared using a batch-style pitched blade mixer. This material was very shear-thinning -- 121,000 cP at 0.5 rpm spindle speed and only 31,400 cP at 3 rpm. A gear pump was used to force the product through the ISG mixer. In a single pass at 4.75 gpm, median droplet size dropped from 19.46 to 4.07 microns. In another run, the base emulsion was fed at a slightly higher flowrate, 6.6 gpm, and the resulting droplet size after one pass was 2.56 microns.



Pilot-scale test set-up

It is worth noting that manufacturers using high horsepower pumps are able to achieve a variety of submicron emulsions through the ISG static mixer.

Conclusion

The role of static mixers in modern manufacturing and processing continues to be an important one. Although they are relatively inexpensive tools, proper design and selection of static mixers must not be taken for granted to ensure optimal performance, high operational efficiency and long-term useful life. Partner with a supplier with extensive experience and a good track record of manufacturing reliable and well-made equipment.