White Paper

LOW HEADLOSS STATIC MIXERS

FUNCTION, DESIGN & USE

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Westfall Low Headloss Static Mixers
Function, Design & Use

Background

Pipe Static Mixers have replaced traditional vat, batch and beater mixers in a number of industries today. Their low cost, low maintenance, high performance, safety and durability have won them acceptance for a wide variety of mixing, blending and emulsification applications.

Westfall Manufacturing Company has had more than 70 years experience designing and manufacturing mixers, originally for the Municipal Waterworks and Waste Treatment industries. The company now supplies state of art in-line static mixers for many other industries including gas, oil and petrochemicals, pulp, paper and process industries. Westfall holds 13 patents for its present mixers.

This White Paper describes the function, design and uses for 2 recently developed models of in-line vane pipe mixers from Westfall.

Introduction

Also called Motionless Mixers, Pipe Static Mixers feature a closed pipe with a variety of fixed inserted devices that alter the flow of liquids, oils or gasses. Alterations include inducing the flow to divide, swirl, recombine, accelerate, decelerate, spread or form layers as they pass through the inserted mixing devices. Often, varying mixture components are added and induced into homogenization as a result of the flow interruptions.

In a pipe, fluids will always mix to some extent because of drag created where the fluid meets the pipe wall. However, this kind of mixing can only be achieved with long lengths of pipe. The insertion of a mixing device into the pipe dramatically accelerates mixing and shortens the pipe length required. The more effective the mixing device, the less pipe length required.

Pipe static mixers have been developed for situations where a constant, fast, reliable and low cost solution is required. Most mixers of this type have no moving parts so they are virtually maintenance free and can be installed as simply as any piece of pipe.

All mixing requires energy to create pressure and move the fluids past or through a mixing device. Pumps or the force of gravity typically provide this energy. One consequence of in-line devices is interference with and reduction in necessary pressure or forward momentum, which is a deciding factor in choosing the right mixer for any given application. Other contributors to pressure or headloss include rough or fouled pipe walls, fittings or welds, material viscosity and number of pipe bends.

Pipe static mixers typically come with a variety of interior design elements depending on the use. These inserts can be geometric, helical or plate-like baffles welded or clamped into place to direct flow and increase mixing turbulence.

Custom-designed and manufactured static mixers provide superior continuous mixing of single or multiple phase operations with repeatable results. The mixing performance can be accurately predicted based on flow rate, viscosity, density, percentage of mixture components and pipe dimensions.

Function

To measure the “mixedness” result of any static mixer design, the radial variation coefficient (CoV) is used. Visualize 2 separate streams, one red, and one blue, entering a static mixer in equal amounts. Each color stream moves in a distinct area. As the two streams are moved through the mixer inserts, the colored streams are induced to swirl and blend together. The colors intermingle and become evenly distributed. While a new color purple emerges, the actual ratio of red to blue has remained the same, i.e., 1:1.

Test samples taken at any point downstream from the mixer will still have a concentration of 50% red and 50% blue. This represents a CoV of 0.0 as there is no variation from the initial concentration even though the new mixture has become completely homogenous.

In most industrial applications, a CoV of 0.05 is considered acceptable. The critical choice of mixing elements and pipe length/size usually reflects the minimum required to reach a 0.05 CoV or less.

All static mixer manufacturers have developed their own designs and tests for sizing. Their designs can be marketed towards specific industries, i.e. wastewater treatment, oil & gas pipelines, food and other process industries.

Other models are more universal in design and function well with any combination of liquid, free-flowing solids and gas.

At Westfall, a patented universal in-line pipe mixer is custom-engineered for a wide variety of uses, including potable water, natural gas, fractured shale oil, processed foods, and retrofits as older infrastructure systems age out. Each mixer is supplied as a complete plug-in pipe module. Alternatively, the interior inserts can be provided along with instructions for welding placement in the home country (thus saving on shipping costs). Extensive documentation accompanies each order.

Design

In aerodynamics, the vortices created by raked wings and gently rounded shapes contribute to keeping a jet plane moving at high speed with high maneuverability. Westfall has adapted these raked design principles to fluid dynamics and developed an in-line static mixer that provides reduced headloss and rapid mixing with minimal energy input, regardless of flow materials.

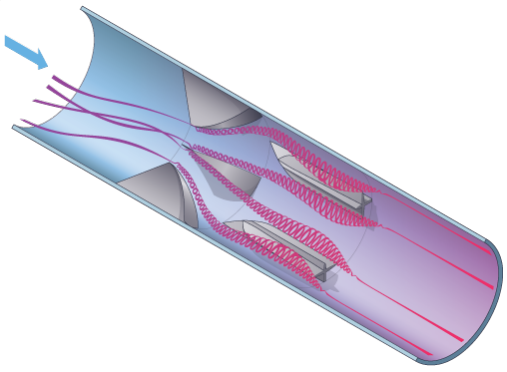
Since the flow of liquids or gases through or across the static mixer elements must rely on gravity or external pumps, low pressure loss or headloss is critical. The shape and placement of Westfall's mixing elements are designed to provide optimal mixing (a CoV of 0.05 or less) without exceeding the maximal allowable pressure loss overall.

In both Models 3000 and 3050, Westfall's patented vanes with gradual inclines can be used to create both flow conditioning and effective mixing with little fouling and minimal headloss.

Westfall Low Headloss In-Line Pipe Static Mixer Designs

- ❑ **Low Headloss Flow Conditioner Model 3000**

This Flow Conditioner consists of a series of vanes or leading tabs coupled with anti-swirl plates welded to interior pipe walls. As a result of the mixer's sloping vane design:



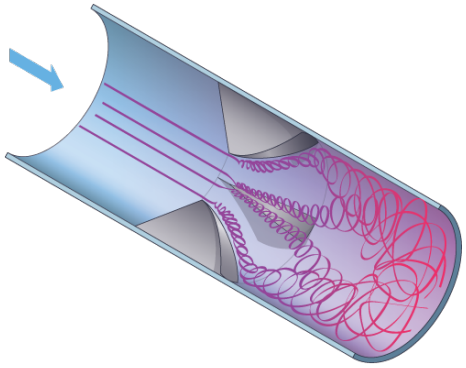
- Flow meter measurement error is reduced.
- A fully developed velocity profile is rapidly established.
-Turbulence is minimized regardless of pipe bends or upstream flow conditions.
-Minimal pressure loss is guaranteed.
-Shortest possible lay length is provided.

Model 3000 Flow Conditioner
US Patent No. 8,322,381 B1
European Patent Pending

The vanes welded to the pipe walls create vortices that mix the passing flow by swirling it “inside-out”. The vortices then quickly dissipate at the pipe wall leaving a uniform flow in its wake. By turning the flow inside out, the flow conditioner is an effective mixer as well, and the low headloss design makes it desirable in applications where pressure head is limited.

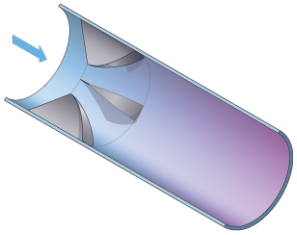
❑ Low Headloss Static Mixer Model 3050

This static mixer achieves a uniform concentration of injected material in a short distance, because the leading tab flow conditioner creates two strong counter-rotating vortices that are generated at the edges of the tabs in the bulk flow away from the wall. These vortices quickly exchange momentum between the flow at the center of the pipe and the flow at the wall.

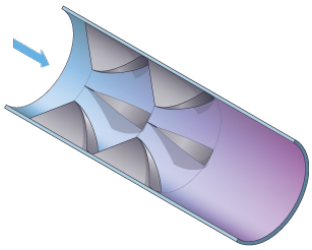


The vane angle, which along with the vortex pairs close proximity to each other, causes the vortices to quickly migrate away from center and towards the pipe wall. The vortices then attach to the pipe wall where they quickly decrease in intensity due to high shear stress at the pipe wall. Rotational momentum is lost. Excessive turbulence is dissipated.

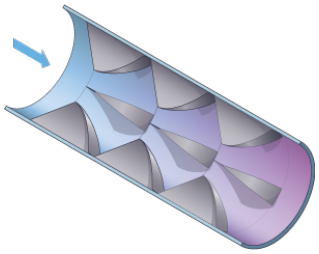
Axial fins effectively eliminate swirl near the pipe wall, where rotational inertia is greatest.



Westfall Model 3050
Single Stage Mixer
Patent No. 8,147,124
CoV=.057
K=0.58



Westfall Model 3050
Two Stage Mixer
Patent No. 8,147,124
CoV=.026
K=1.13



Westfall Model 3050
Three Stage Mixer
Patent No. 8,147,124
CoV=.014
K=1.64

Tapered leading edges throughout, along with other subtle geometric features, help to prevent fouling and headloss.

Research

Alden Laboratories originally tested the Model 3000 mixer for **pressure loss**, both with and without the straightener vanes installed. From the results, a K-value of 0.556 was calculated using the pressure loss value and a water density of 62.5-lbm/ft3.

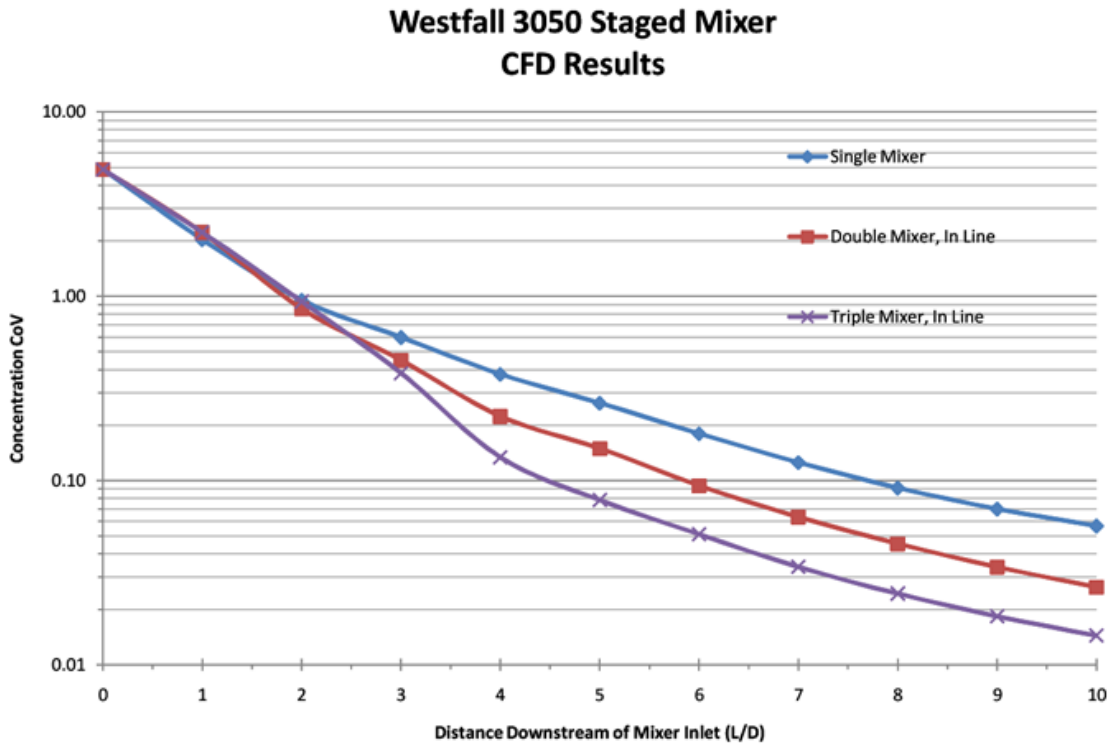
Then the model was also tested for its **mixing effectiveness** (Model 3050) by placing 4 injection quills at the upstream edge of the mixer (LD=0). The ends of the quills were placed on the area centers of the four quadrants of the pipe's cross-sectional area.

Additionally, a control case was tested with four injection quills and no mixer to test the benefit of having the mixing elements installed.

The injection locations performed significantly better with the mixer elements than without. Injecting the solution directly in front of the tabs proved most effective at distances of more than 4D downstream, and achieved a CoV of less than 0.03 by 10D downstream of the injection ports. Without mixing elements, the CoV was 0.18 at 10D.

Alden Labs recommended that when used as a mixer, four injection points be placed directly upstream of each of the four leading tab mixing vanes, at a penetration depth of 7.2" from the wall in a 36" I.D. pipe.

Regardless of the number of vane stages, the Westfall pipe mixers cause 2 to 4 times less headloss than competitor's mixers.



Construction

Pipe walls are thoroughly polished and often coated to reduce headloss. Mixer elements are welded to pipe walls in pipes measuring from 2" to 72" I.D. All welds are certified by an outside independent firm, Thielsch Engineering, prior to shipping. Interior elements are supplied as a complete modular pipe unit with threaded or flanged ends. Elements can also be supplied as independent units to be welded in place in country.

Materials

Mixers are made from a variety of materials depending on customer needs, fluid materials and need for protection from corrosion, chemical damage or fouling. Materials include stainless steel type 316 or 304 and carbon steel.

Other Options

Options include but are not limited to built-in injection and sampling ports or quills, and sanitary finish for food and pharmaceutical processing, All pipe mixers are available with threaded or flanged ends.

Sizing

Westfall specializes in over-size installations. The diameter of the static mixer is usually the same size as the process pipeline. The number of in-line stages depends on the degree of mixing required (estimated by flow rate, viscosity, density and percentage of the smallest component). Increasing the number of elements or stages improves mixing efficiency but also leads to greater headloss.

For example, in designing the recently installed pipe mixer for Gassco in Emden, Germany, various configurations were tested. The German engineers decided on the 2-stage **3050** mixer, which was slightly less efficient as a mixer but generated sufficiently reduced headloss to support desired gas flow across the North Sea to a new port terminal in Emden.

Durability

The simple universal design of the Westfall pipe vanes, when securely welded in place, have proven through CFD and FEA test analysis to last under harsh conditions for more than 30 years. This is why the Westfall design is chosen over other international competitors for bids such as the GASSCO project in Germany.

Documentation

Because Westfall conducts extensive testing on its Static Mixers, each larger order comes with in-depth documentation, which may include reports by Alden Labs, the Naval Underwater Warfare Center and Thielsch Engineering. Custom prototypes are made and extensively tested for specialized orders.

Use

Westfall Low Headloss Static Mixers are used in many industries, including: water, wastewater, oil, gas and petrochemicals, pulp and many kinds of processing industries. In the latter case, they are typically used for applications like mixing thickening agents into sauces or fruit into yoghurt. Westfall Mixers are NSF Certified for safety in food use with 316 SS, CPVC, Hastelloy or PVC.

8" Westfall Model 3050 "Low Headloss" Single Stage Mixer
This basic mixer illustrates the vane shape and placement for generating highly efficient and compact mixing with low headloss. The graduated slope of the vanes allow bulk materials and threads to pass through without nesting or fouling. The symmetrical placement of the vanes contributes to the mixer's efficiency and low CoV rating.

16" Westfall Model 3050 3 Stage Mixer

Dissolving peracetic acid into influent water at 4,620 gallons per minute flow rate for gas well fracking in Oklahoma.

12” Westfall Model 3050 Low Headloss Mixers
Ready for shipping. These 12 in-line static mixers will be bolted into Canadian gas pipelines and used to blend biodiesel fuels.

48” Westfall Low Headloss Static Mixer Model 3050
Ready for welding in place to blend gases from 2 Gassco pipelines off the Norwegian Continental Shelf for a new natural gas terminal in Emden Germany. Under a special licensing agreement, the engineering company, Linde Engineering, fabricated and welded the vanes in place in Germany. This represented a significant cost savings to Gassco.

CONCLUSION

The function, design and use of Westfall's Low Headloss Pipe Static Mixers continue to lead the way in the growth of modern fluid dynamics and all processing applications. When properly designed and engineered, these mixers are extremely durable, effective and relatively low cost. They are easy to install. When ordering any kind of static mixer, choose a supplier with deep experience and a track record of building innovative equipment that is proven to last a minimum of 30 years.

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List of Sales Reps: www.westfallmfg.com/contact/