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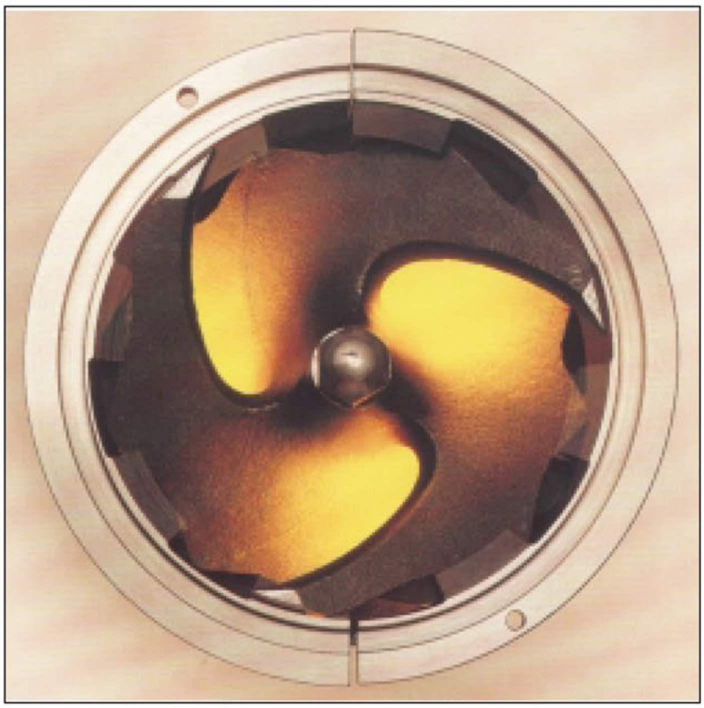

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Consider More Than Static Mixers

A number of technologies can handle pipeline mixing

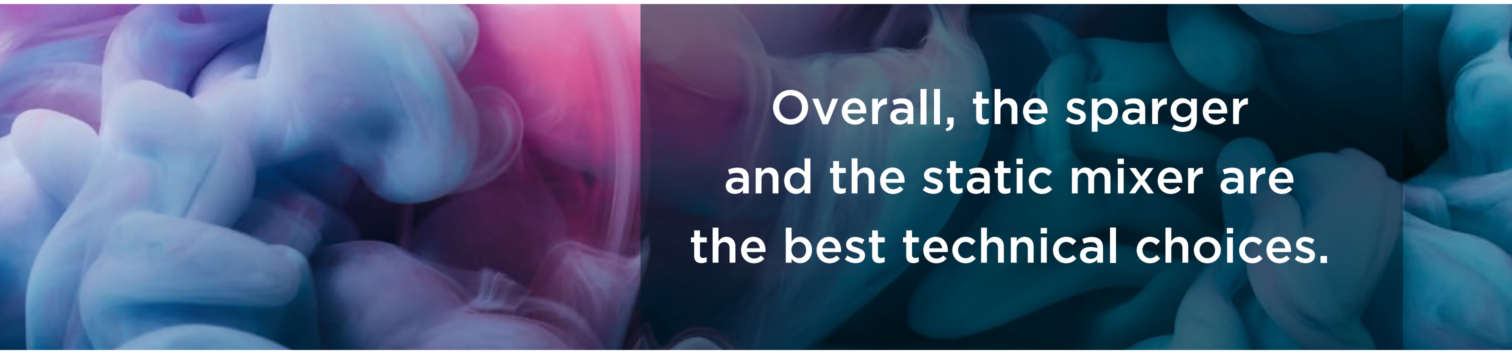
By Andrew Sloley, Contributing Editor

The term "pipeline mixing" covers mixing of materials in a flowing line downstream of a junction. The mixing may involve miscible liquids, immiscible liquids and multi-phase mixtures. Options include just letting materials mingle naturally, using pipe fittings to spur contact, and installing static mixers, spray nozzles or spargers. Static mixers now dominate pipeline mixing — but that doesn't mean they're always the best choice.

Let's consider a recent case that involved choosing a better pipeline mixer for a liquid/liquid service that included mixing both miscible and immiscible liquids.

This application has two mixing steps: (1) mixing two miscible liquid reactants; and (2) adding the reactants to an immiscible liquid catalyst. Some reactions take place at the interface. Others occur inside the catalyst phase after the reactants dissolve into the catalyst. The catalyst-to-reactants ratio is roughly 1:1 by volume; the catalyst has the same volume as the total reactants in the system. Neither the reactant phase nor the catalyst phase is well defined as either a continuous phase or a discontinuous phase.

The idea was to improve yields by more-thorough reactant/reactant and reactants/catalyst mixing. This would increase inter-phase surface area, which would help both types of reaction mechanisms. The current setup relies on a simple pipe junction upstream of the reactors. We evaluated a spray nozzle, a sparger and a static mixer as a possible replacement.



Conventional spray nozzles accelerate a liquid to create a jet. The liquid then breaks up into smaller droplets. The major types of spray nozzles that might be used here are based on (1) rotating flow in a chamber that exits 90° from the liquid inlet, (2) swirl imparted by an internal vane or (3) a narrow stream cut by a spiral blade (pig tail).

These nozzles form droplets primarily through a combination of liquid ligament breakup and slicing of liquid sheets leaving the nozzle. Both mechanisms vary with liquid velocity, surface tension between phases and other physical properties. Jet instability is a key factor in making lots of drops. The little data available show most mixing velocity is shed within 12 in. to 18 in. of the nozzle. No significant droplet formation occurs because the original liquid ligaments or sheets don't form.

A sparger is a pipe with multiple holes that create a pressure drop forcing flow to distribute across the holes. (This pressure drop only is imposed on the liquid being injected, not the entire stream.) With the sparger installed into the main line, the injected flow of one stream would enter the second stream. The sparger could be aligned either across a larger pipe (at 90°) or along the same flow line as the larger pipe.

As with a spray nozzle, enhanced liquid mixing comes from local turbulence created by injecting a high velocity liquid into a second liquid. The mixing is likely at least as good as that of a spray nozzle. Design and installation of a liquid sparger typically is both cheaper and simpler.

Static mixers have become dominant for good reason. They use vanes or blades as elements. This enables mixing to occur at relatively low pressure drop, as little as 10% or 20% that of a sparger. The only potential downsides are that a static mixer often requires a longer straight pipe run for installation and pressure drop is applied to the entire stream.

Overall, the sparger and the static mixer are the best technical choices. Both have proven track records. In contrast, the spray nozzle, which is designed for liquid injection into gas, rarely is used in liquid/liquid services and should be avoided.

Despite this, the plant has opted for spray-nozzle injection for both mixing tasks. It considered spray nozzles proven technology because they have been used in this process by other plants. Here, though, hydraulic constraints limit the pressure drop to a fraction of that at other units; so results may not be as good.

Not agreeing with a decision doesn't free an engineer of the responsibility to help the site derive the most benefit possible from its choice. So, we recommended use of pig-tail-type nozzles. These mechanically "cut" a solid liquid stream into sheets but don't form as uniform droplets as the other types in conventional services. However, their mechanical design is guaranteed to at least do something. The cutting action will improve liquid/liquid mixing somewhat. Also, the cutting edge acts as a minor mixing element in its own right. ●

ANDREW SLOLEY is a contributing editor for *Chemical Processing*. Email him at ASloley@putman.net.

Carefully Evaluate Blending Requirements

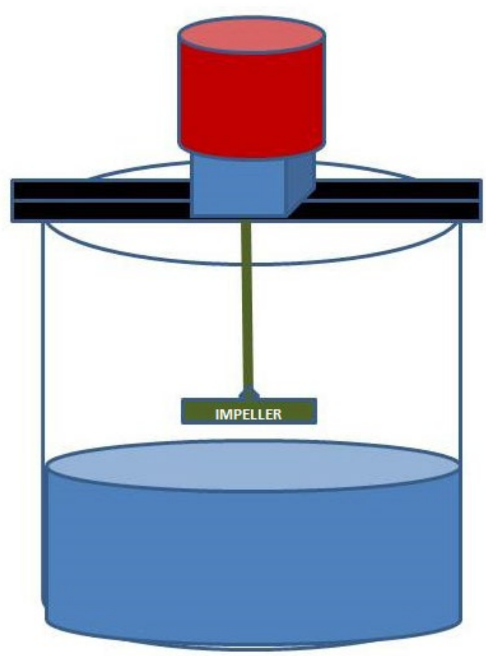
When choosing a mixer, consider these four key components that can lead to improved mixing

By Roy R. Scott, Arde Barinco

It is not unusual for mixing suppliers to receive the following request, or similar: "I need a mixer for a 500-gal. tank." The requestor then may expect a product suggestion to satisfy all requirements. The supplier's typical response is, "What is your mixture's viscosity?" Many times, this is the entire conversation, and a mixer's specification and pricing proceed from there. This often can lead to dissatisfying results. Here are four things to consider for successful mixing.

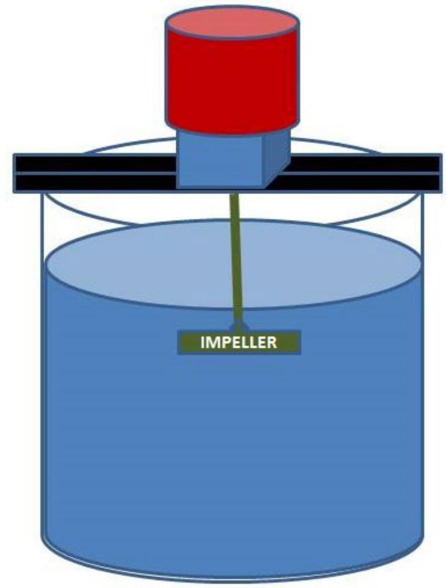
1. MAKE SURE IMPELLER IS IMMERSED

All batch mixers use some type of impelling device that typically is connected to a shaft driven by an electric motor. That impeller, sometimes known as a rotor or a propeller and other times as a turbine, must be in sufficient contact with the mixture if it is going to have any success impelling that mixture (Figure 1).



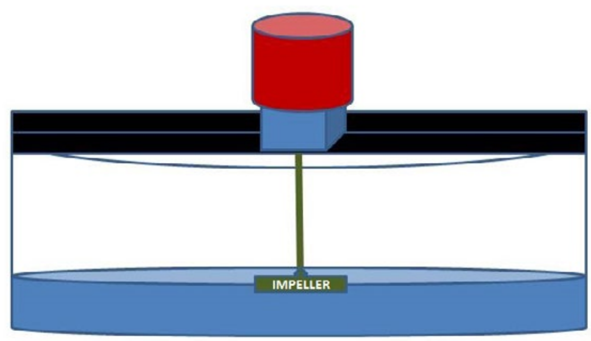
IMPELLER LENGTH
Figure 1. Impeller shaft must be long enough to reach liquid mixture.

This may seem obvious, but the details of the process vessel's shape determine the details of the mechanical design of the shaft connected to the mixing impeller. In short, the impeller's drive shaft has to be long enough to reach down into the liquid at all times if mixing is to proceed. If the mixing vessel usually is close to full, then the mixing impeller will make good contact with the mixture in almost any circumstance (Figure 2).



PROPER CONTACT
Figure 2. This impeller is well covered and in contact with mixture.

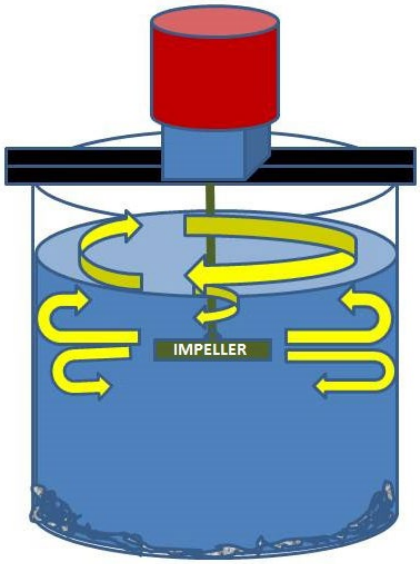
If the batch begins with the vessel half-filled and the other half of the mixture must be added while mixing, then the mixing impeller must make good contact with the liquid even when the tank is half-full. This result is even more difficult to achieve if the vessel needs to be stirred at a less-than-half-filled level (Figure 3).



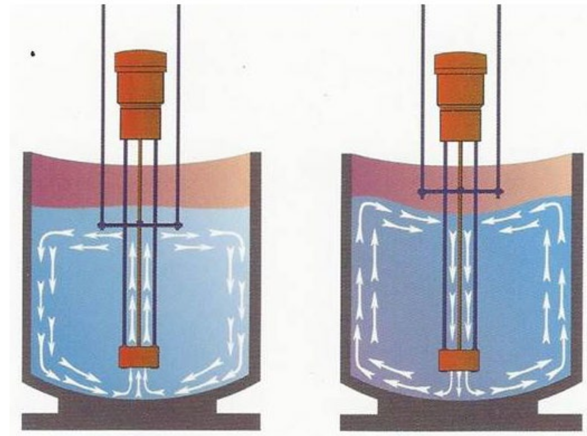
FILL LEVEL
Figure 3. Here, the fill level is too low to cover the impeller and the mix vessel is too wide and shallow.

The mixing vessel's diameter and depth will determine how much volume exists at a given fill level. These dimensions are required to calculate the fill levels to make sure that the impeller can impel the mixture. Most impellers require some minimum immersion, such as 6 or 12 in. of mixture over top of the impeller, to do the job.

After the mixing impeller is configured and located so that it can start doing its job of pumping and moving the mixture throughout the mixing vessel, the pumping and circulation must be strong enough to mix all areas in the mixing vessel. No stagnant locations can exist because, if any of the mixture's components enter an area with no flow, they will, by definition, stay there and not get mixed with the other components (Figure 4).



POOR FLOW
Figure 4. Impeller is well covered but good flow doesn't reach lower areas of vessel, allowing settling to occur.



Upward "umbrella" flow **Downward "vortex" flow**

FLOW PATTERNS
Figure 5. These mixers operate at very high flow rates that cause natural high shear flow patterns to produce good mixing.

2. MAKE SURE IMPELLER IMPARTS FLOW TO ALL AREAS OF MIX VESSEL

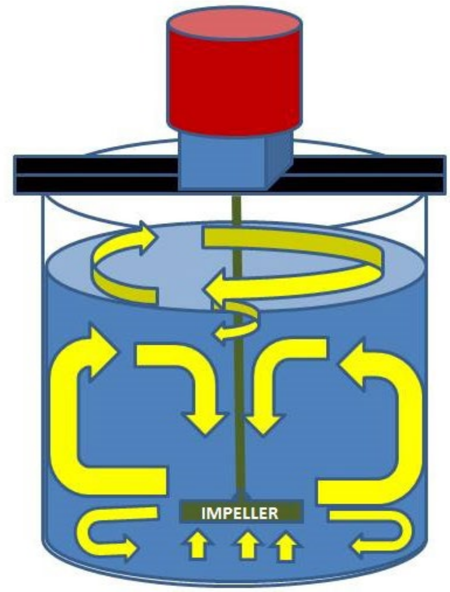
The mixer supplier must offer an impeller capable of moving the mixture throughout the vessel, and that impeller will require a certain amount of mechanical power. The mixer manufacturer must configure a power source (motor) along with its shaft and impeller that can pump the mixture's viscosity and density. However, just causing good flow from top to bottom and round and round may not produce any mixing at all. The impeller must produce a pattern of flow that causes swirls and eddies that can intermingle the various components.

Sometimes the impeller-produced flow needs to be baffled by installing stationary vertical obstacles in the mixing vessel. Other mixers operate at very high flow rates that cause natural flow patterns to produce good mixing without the installation of baffles (Figure 5). Once there is sufficient flow to produce different velocities within a mixing vessel, these shearing zones then can produce the desired result (Figure 6). That is, all of the various components must exist in the correct percentage for whatever sample size is taken from the mixing vessel. *This is the definition of successful mixing.*

3. MAKE SURE MIXING QUALITY GOALS ARE MET

Even if the mixer has impelled all of the various components into the correct percentages, additional quality requirements may exist, such as a desired particle size distribution of a solid dispersed into a liquid or an emulsion droplet size distribution. Perhaps solids need be dissolved into the liquid at a given concentration.

Mixing quality can be measured in different ways. Different desired process results often will require different types of mixing equipment. For fine-particle-size dispersion, mixing equipment generically described as "high shear" may be required. However, "high shear" can refer to thousands of mixer types. In short, the mixing impeller not only must mix the components to the right ratio but also may be required to achieve some other physical or chemical result.



SUFFICIENT FLOW
Figure 6. Impeller is well covered and close enough to the vessel bottom to reach lower areas of vessel to prevent settling.

4. MATCH BATCH COMPLETION TIME TO REQUIRED OUTPUT

One more requirement for a mixer to be successful is that it must do everything described above and also do it in the right amount of time. For a 500-gal. batch, it has been assumed the mixer will produce the volumes required for the mixer's owner. How much of the mixture needs to be made, and how much per day and how much per year?

Suppose the annual requirements are 100,000 gal. Mixing time for a 500-gal. mixer includes filling the vessel, adding the other required components, mixing, dispensing and cleaning the vessel to make it ready for the next batch. If these steps take an 8-hr. shift, then it would take 200 days on a one-shift basis to make the required 100,000 gal. Because a typical work year is 200 days, the mixer is successful. However, if 200,000 gal. are required annually, the facility would have to go on a two-shift basis or install two 500-gal. tanks.

Another alternative would be to specify a faster mixer that might complete the mixing process twice in one shift. The decision to use the 500-gal. mixing vessel size might be reconsidered. Perhaps a larger batch with a larger, faster mixer would cost less than starting a second shift.

Extensive research for blending applications is available in a number of textbooks. However, for many processes, no substitute exists for doing experimental trials on a small scale and then scaling up.

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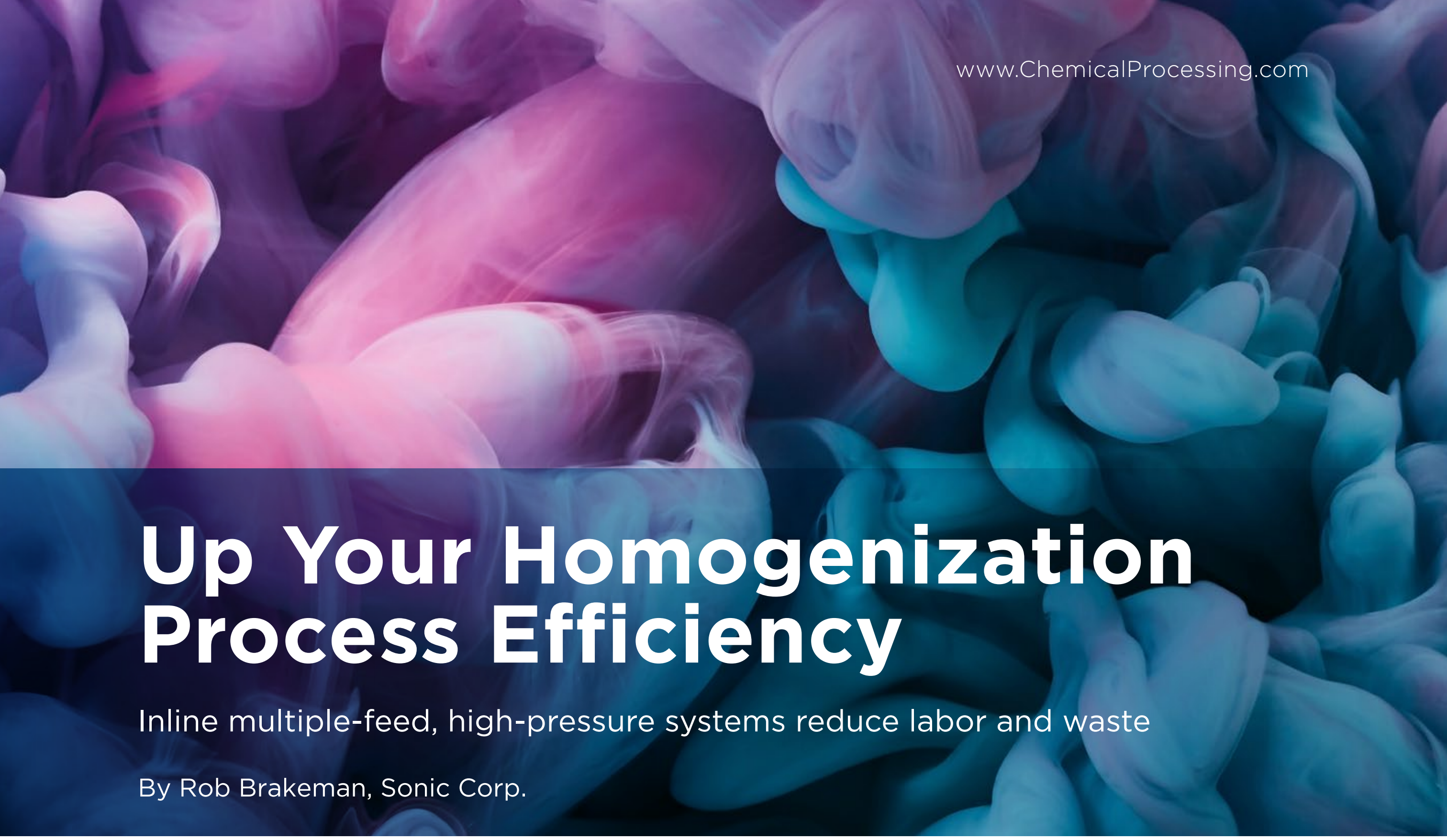


Up Your Homogenization Process Efficiency

Inline multiple-feed, high-pressure systems reduce labor and waste

By Rob Brakeman, Sonic Corp.

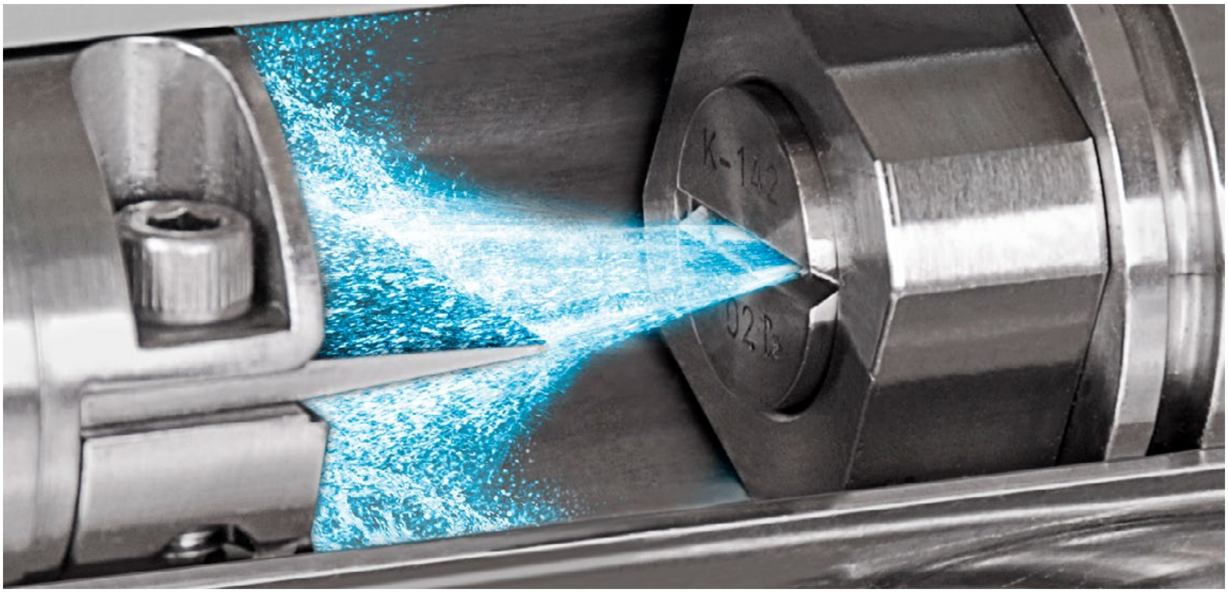
Three methods of homogenization are available for processing incongruous fluids to create uniform emulsions. The first type is *a rotating high-shear prop*, such as a Cowles blade. Next is *a rotor/stator high shear-style mixer* that uses mechanical rotational shear along with a restrictive stationary screen to essentially beat an emulsion into existence. Mechanical shear tears the discontinuous or oily phase into smaller droplets, allowing for a suspension. The third type is *a high-pressure homogenizer* that uses a restriction in the line that subjects fluid to instant acceleration and cavitation (Figure 1).

The acceleration comes from forcing the fluid via a positive displacement (PD) pump through an orifice nozzle or a partially closed valve, whereby the fluid accelerates over a short distance to maintain flow rate through this restriction in the line. The cavitation comes from the voids formed as the fluid changes speed over a very short distance. Some high-pressure homogenizing devices use a blade in the fluid path to create additional cavitation.

SINGLE-FEED UNITS

In many instances, rotating mechanical shear homogenizers come as single-feed units that are used inside a tank or inline underneath the tank, usually in a recirculation loop. To use these, the processor is married to a batch method that can be labor-intensive and requires feeding various ingredients to the tank manually one at a time.

In the best cases, factories have devised methods to transfer these materials automatically to reduce labor but still meter the



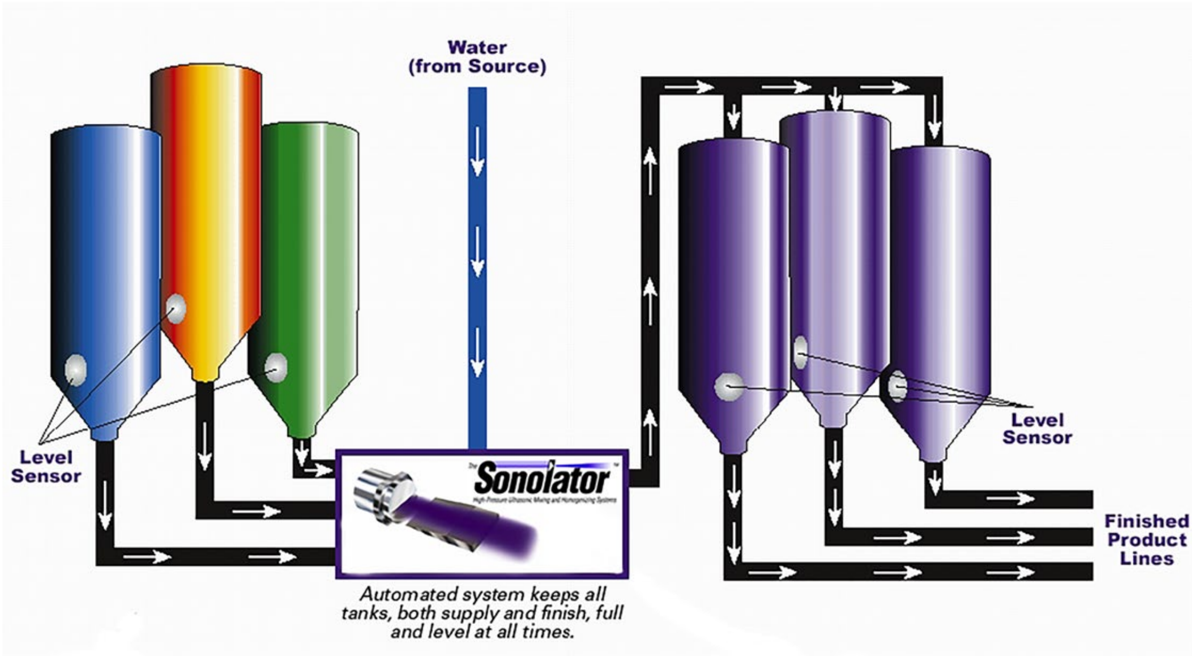
INLINE HOMOGENIZER
Figure 1. This inline homogenizing device, known as a Sonolator, uses fluid acceleration and a sharp blade in the fluid path to create cavitation.

ingredients singularly based on weight gain in a tank on load cells. Other manufacturers have taken it a step further and employed mass or volumetric flowmeters to dump materials simultaneously.

Although efficiencies have been created by doing this to reduce labor involvement, all materials ultimately must be transferred to a single large batch tank and the inbound transfer times, mixing times and transfer out times all add up. Operator involvement still is heavy as these transitions from material feeding to mixing to transferring out need to be overseen and managed. Things get worse when higher temperatures are required to heat various materials that require heating to be liquid or to do their job. It's even worse still if order of addition rules need to be followed, meaning A must precede B for C to be dumped next, and so on.

All of this leads to a large tank with a lot of fluid, much of which could be water, and much, or all, of which now could be at elevated temperature. Water in a tank is wasteful in so many ways. Tank space is precious, so it behooves any manufacturer to reduce the amount of fluid that needs transferred to a tank.

Take a typical lotion emulsion, for instance. Most manufacturers start with two tanks — an oil phase and an aqueous phase, both hot. The aqueous phase might be as much as 60-70% plain water. The two premixes then are merged to a single tank, homogenized and cooled. In some cases, this can be a tragic 12-hour process, most of which is heating and



MULTIPLE-FEED INLINE HOMOGENIZER SYSTEM
Figure 2. In this multifeed inline Sonolator homogenizer system, a hot oil phase, room temperature water and ambient aqueous phase are metered at high pressure to make an instant emulsion inline.

cooling time as well as the transfer time to merge the two premixes to a single tank and transfer out a cooled, more viscous lotion.

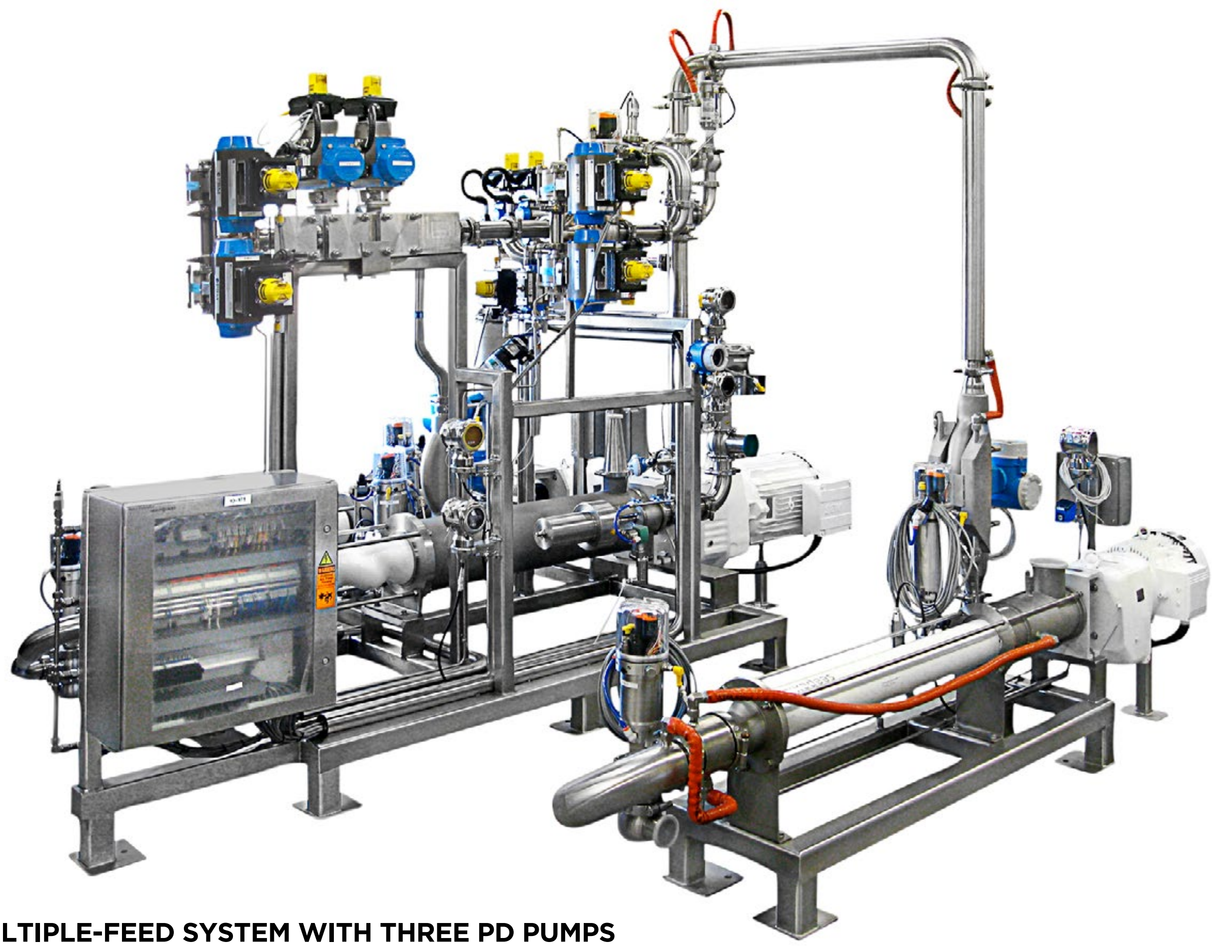
MULTIPLE-FEED SYSTEMS

A more efficient and time-saving method can be used: inline multiple-feed high-pressure homogenization. This method uses an inline homogenizing device, such as the Sonolator device described earlier, that is coupled to several PD pumps in an integrated and preprogrammed system that meters bulk materials, water and smaller, more manageable premixes inline to form an emulsion instantly that often doesn't require any cooling.

In the above example with lotions, the process can be made more efficient by using a dual-feed homogenizing system that meters the two premixes at ratio and subjects the combined stream to anywhere from 500 to 2,000 psi and creates an emulsion inline (Figure 2).

Take it a step further, and you can reduce the aqueous phase's temperature. The only reason this phase is elevated in temperature is to allow for a gentle merging of the two tanks. When they are merged inline at high pressure, the phases' incoming temperatures can be different, and you get a cooler emulsion that now looks very close to your fillable end product.

Cooling time is reduced significantly, or even eliminated altogether, and the transfer time is absorbed into the emulsion-making time,



MULTIPLE-FEED SYSTEM WITH THREE PD PUMPS
Figure 3. This multiple-feed system features three PD pumps with mass flowmeters and inline homogenizer device.

so it's a time-saving win. And you now can remove anywhere from 25-50% of the water from that aqueous phase and meter it directly from the deionized (DI) water supply using a third PD pump and flowmeter that would be integrated into the system (Figure 3).

This example, give or take, can be seen in all industries. A simple example in the chemical industry is metering silicone fluid, water and a surfactant at proper ratio through an inline homogenizing device at high pressure to create a uniform emulsion. No batch tank and no premixing of any type are required.

In textiles, neat oils that apply to yarn better when emulsified with water typically use only three ingredients that can be metered from bulk and emulsified inline, again without batching tanks.

Another feature of the inline multiple-feed homogenizing method is increased product yield for given tank space. In those cases in which a premix was necessary, to allow for minor solid ingredients, etc., you want to yield as much finished product from that one tank as possible and minimize the amount of water used in the premix.

MULTIPLE-FEED SYSTEM FOR PERSONAL CARE FLUIDS
Figure 4. This is a production-scale, multiple-feed Sonolator homogenizing system used to process personal care fluids that use SLES, water and other ingredients. The system makes 20 tons of product using only a 5-ton aqueous premix tank.

In personal care, an aqueous premix is required and is metered alongside DI water, sodium lauryl ether sulfate (SLES) and other soap-based raw ingredients not placed in a tank to make shampoo and body wash inline. Because the premix winds up being approximately 25% or so of the total volume, you now can make three to four times as much product with a single tank as any batch method. This is because the remaining balance of water, SLES and other bulk materials are homogenized inline directly from their respective sources (Figure 4).

CONCLUSION

Moving away from tank and batch processing and into this world of multiple-feed processing will almost always save time and money. It will reduce labor involvement and reduce errors and waste. One of the hurdles to looking into this approach is the idea that making emulsions is actually tricky. It's not like dealing with miscible fluids that play nice with each other. Oils and water need to be forced together; they don't like hanging around in a tank together for very long. Avoid this issue by keeping water out of those tanks.

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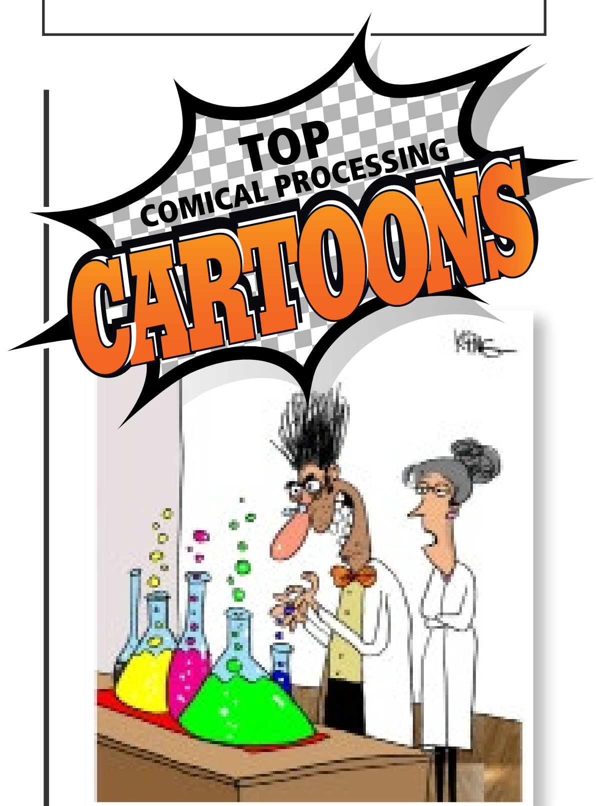

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