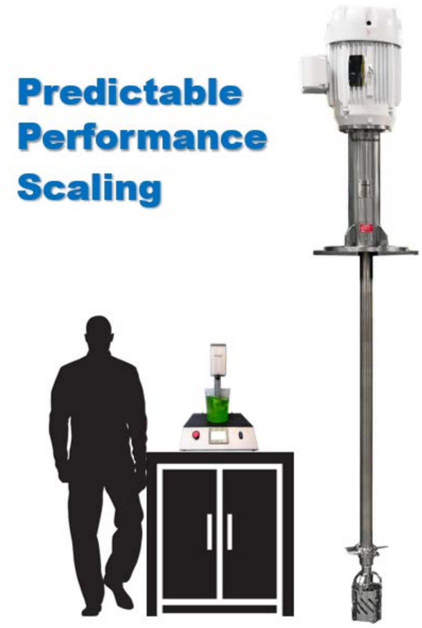
SUCCESSFUL SCALE-UP

OF HIGH SHEAR BATCH & INLINE MIXERS

Scale-up of mixing machinery has become a key issue with processors as development times have been reduced, and new products are brought to market at very quick speeds. Testing formulations in small beakers or 5-gallon pails is often the only testing done on some products, and a leap of faith is taken that the process will scale to large tanks with similar results.



Admix recently released a Technical Report detailing how to succeed with the scale-up of mixers from a 3-liter beaker right up to a 1000-gallon (or larger) production vessel. Scale-up of high shear mixers is a particularly challenging issue as many the variables typically observed with low-speed agitators do not apply. The most critical parameters that may be used for conducting small-scale tests and resizing similar machinery for the full-scale application are as follows in order of importance:

1. Intensity

This parameter is related to Bulk Fluid Velocity as practiced by some agitation companies and is expressed in feet per second. Intensity takes into account the process fluid velocity, pumping rate, volume of the vessel, and the distance traveled by particles or molecules in the batch. Intensity values can range from a low of 3 to a high of 30 or more, with an average value from 8 to 12. These “average” values roughly equate to bulk velocities in the 40 to 60 fps range, considered quite vigorous for low-speed agitation.

Helpful Hint: If no other parameter was available, scaling the Intensity would provide a better than 90% success in the full scale.

2. Tip Speed

Tip speed is the peripheral velocity of the mixing head, as opposed to the bulk fluid velocity. Most high-speed mixing applications can be completed with a tip speed of 35 to 60 fps. Tip speed only considers the speed of the mixer and the rotor diameter, and ignores the impact of viscosity, volume, and specific gravity on fluid behavior. For this reason tip speed is a useful tool but is not sufficient by itself to insure 100% scale-up success.

Helpful Hint: High tip speeds are critical for maximum particle and droplet size reduction.

3. Tank Turnovers

Tank Turnover is a measure of how effective a mixer’s pumping rate is relative to turning a batch over a particular number of times a minute. To make this calculation, the pumping rate of the mixer is divided by the volume of the batch. Tank Turnover is a widely used parameter for scaling low speed turbine agitators but has not been sufficiently used by most high shear mixer suppliers.

This is understandable as the geometry of most high shear mixers are not designed to provide high flow or pumping rates, but instead focus on shear capabilities. For small vessels (under 30 gallons) where the shear head can provide enough flow, as limited as it may be, it is still adequate to circulate the fluid volume to eventually produce the desired mix. The difficulty in scaling becomes dramatically evident as these same “low flow” high shear mixers are placed into much larger vessels where lack of pumping and product turnover eventually causes the process material to “freeze up” whereby there is little visible motion. This is especially problematic with high viscosity, thixotropic or other non-Newtonian materials using gums, thickeners, or stabilizers.

Look for a high shear mixing device that features an upper or lower high flow impeller to help drive the process fluid through the mixing head many times a minute, insuring quicker homogeneity and more predictable scale-up.

Helpful Hint: While Intensity and Tip Speed should be scaled completely proportional, the number of tank turnovers is going to be far greater for the lab mixer than with the production mixer. The objective therefore is to insure a minimum turnover value in the large tank and not try to match the lab mixer.

4. Geometric Similarity (D/T)

It is desirable to match the ratio of mixing head diameter to tank diameter as you progress from the lab vessel to the full size production vessel. This insures that the flow control “profile” observed is similar in both vessels, such that there are no obvious “dead zones” or unmixed areas of the larger vessel.

Helpful Hint: A minimum D/T of 0.1 is desirable for most high speed applications, i.e. a 6" mix head within a 60" tank diameter.

What Batch Sizes Are Best for Scale-Up?

We find that for most lower viscosity mixing applications, scaling from a ½ gallon (2 liter) beaker direct to a larger 100 to 200 gallon production vessel is safely and accurately accomplished using the methods above. For moderate to high viscosity fluids, or where production batches exceed 250 gallons, we highly recommend an intermediate step in the scale-up process. Typically, this would be a 5 to 10 gallon batch size, which we make available as our “pilot plant” models, available at our lab facility or at our customer’s location through our regional offices. In extreme cases where we are working with both a high viscosity product and a production volume greater than 750 gallons, an additional scale-up test as large as 100 to 150 gallons is recommended. While 3 smaller scale tests may seem excessive and time consuming, it is a small price to pay for insuring 100% accuracy and scalability in the larger, substantially more expensive full scale production vessel.

Scale-Up of In-Line Mixers

Closed loop continuous flow in-line mixers, as well as those used to recirculate through a batch process, are becoming extremely useful and successful in sanitary processing. In-line high shear mixers are very fast, provide very consistent results, and are very easy to add on to an existing process or production line.

While scale-up of these mixing devices is not as difficult as with batch mixers, it still needs to be considered. Selection of a high shear in-line mixer is primarily based on the required flow or transfer rate dictated by the production line. Most in-line mixers are offered in various sizes to cover the typical flow rates (from 10 to 300 GPM) utilized by most plants.

Tip speed must also be considered, and here again, most in-line mixers provide very aggressive tip speeds ranging from 40 to 90 FPS or higher. The challenge in scaling in-line high shear mixers surfaces when process viscosities are greater than 5000 CPS, or where the application requires the addition of powders for in-line wetting out, dispersion and hydration. With higher viscosity process streams, flow rate through the mixer can be drastically reduced, thus reducing the flow velocity and probably affecting the outcome of the mixture. Higher flows can be generated with the addition of an upstream pump to “feed” the process fluid at a higher velocity into the in-line mixer. Flow velocity therefore presents a third parameter which needs checking while scaling up, as the “hydraulic shear” provided by high velocities will improve both particle and droplet size reduction and distribution. To ensure consistency of particle analysis in varying flow and velocity ranges, a scale-up program that incorporates flow velocity, pumping capacity, tip speed, viscosity, and density is necessary (similar to the Admix “Intensity” program discussed earlier).

Admix, Inc. offers a wide range of sanitary equipment to suit all your mixing, blending & particle size reduction needs whether you require **in-tank batch processing, inline mixing & milling or powder induction & dispersion**.

Contact us for information our high-speed dispersers, high shear emulsifiers, inline emulsifiers & wet mills, static blenders, low speed stainless batch mixers & powder induction & dispersion systems.

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