

# SES Process Technology Group



A DIVISION OF STRESS ENGINEERING SERVICES, INC

## Squeezing the Uncertainty Out of Scale-up

*The process works well in the lab. Mixing is easy, reactions are complete, handling is simple. Now it's time for the pilot plant or full-scale production.*

***That means scale-up and scale-up means pain and uncertainty.***

What makes scale-up so tough? The rules are clear: establish geometric similarity, establish dynamic similarity, apply the scaling equations and you're done. Yet scale-up often fails.

### TOP REASONS WHY SCALE-UP FAILS

- ❖ Use of existing equipment breaks the scaling rules.
- ❖ The ability to transfer large amounts of power, heat, etc. to a batch at lab and pilot scales masks problems that will appear at full scale.
- ❖ Reaction rates do not scale.
- ❖ The need to use actual product at lab and pilot scales eliminates the opportunity to achieve similarity by using "model" materials.

### THE SES SOLUTION — A PHYSICS-BASED APPROACH TO SCALE-UP

SES believes that a deep understanding of the physics of process unit operations can shortcut most scale-up problems and we build this understanding into every scale-up program we conduct.

#### STEP 1: Model the Process Physics

Construct a model incorporating all of the important physical and chemical phenomena. This model may be as simple as a scaling formula or as complex as a Computational Fluid Dynamics computer simulation.



#### STEP 2: Validate the Model

Validate the math model against "cold-flow" laboratory simulations and available process data. Applying the model to lab and pilot scale data builds confidence in the ability of the model to predict real-world phenomena.

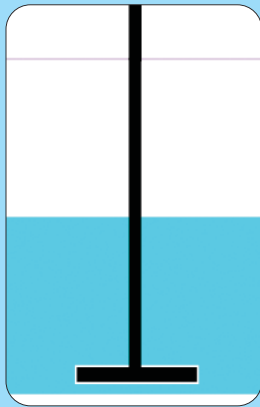
#### STEP 3: Scale with Confidence

Apply the model to predict performance at full scale and use it to guide process optimization.

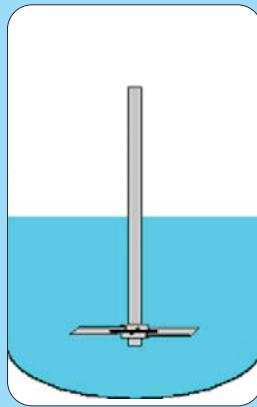
SES has used this approach with success to scale a wide range of operations, including mixing, spray drying, liquid filling, transport, filtration, separation, and catalytic reaction processes.

## CASE STUDY: MIXER SCALE-UP

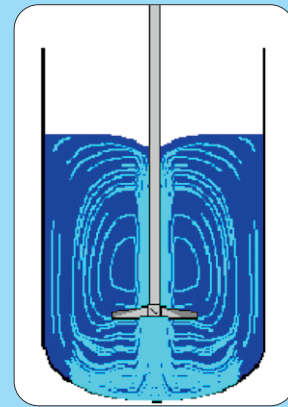
**GOAL:** Transfer technology from lab to pilot-scale and production-scale.



Lab-scale (Magnetic stirrer)



Pilot-scale  
(Disk-turbine impeller)



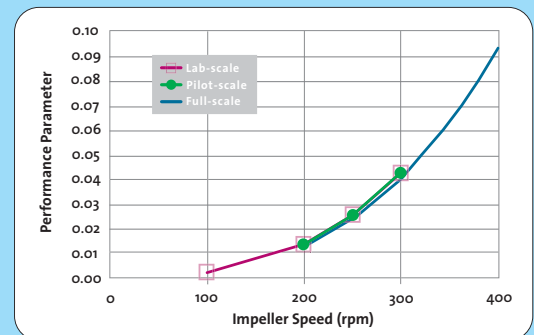
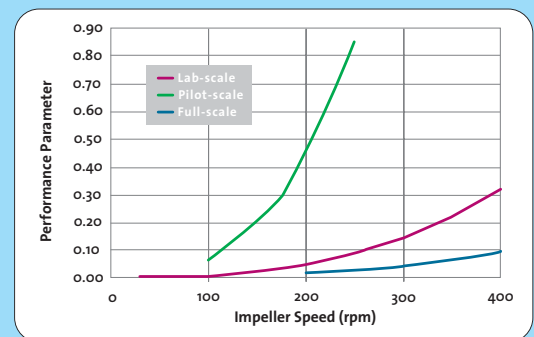
Production-scale  
(Hydrofoil impeller)

**CHALLENGE:** Mixing equipment size and type differ at each scale. The disparity in equipment size and type introduce problems in transferring a well-developed lab-scale process to production-scale. The performance differences are highlighted by comparison of a key performance parameter in the accompanying figure.

**SES APPROACH:** Identify the key mixing parameters and match the performance at all scales using an integrated physics-based approach that includes:

- ❖ Correlations based on measurements and data.
- ❖ Modeling tools based on empirical data and 1-D conservation equations.
- ❖ Detailed simulation technology such as Computational Fluid Dynamics.
- ❖ Experimental measurements in scaled-down physical models.

**RESULTS:** Improved mixing configurations were evaluated and the mixing performance was matched at all scales. The mixing performance of revised configurations is depicted in the accompanying figure, indicating that good scaling has been achieved.



## SES Can Help Make Your Next Scale-up Project a Success

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