APPLICATION NOTE

Optimizing Bioproduction and Scale-Up

Magnetic mixing systems with scalability from lab to production

INTRODUCTION

In today's rapidly evolving biopharmaceutical landscape, manufacturers face increasing pressure to deliver high-quality products while accelerating timelines and reducing costs. From early-stage development to full scale commercial production, every process step must balance flexibility, scalability, and control. To meet these expectations, core unit operations must perform reliably at every scale. Mixing stands out as a critical operation because it needs to maintain product homogeneity and integrity without compromising sterility. Traditional mixing technologies can present challenges when transitioning from small-scale to large-scale manufacturing including differences in mixing behavior, cleaning requirements and operational complexity.

Avantor® Magnetic Mixer systems are designed as magnetically driven, single-use mixing platforms intended to support buffer and media preparation under aseptic conditions. Utilizing magnetically driven impellers in a closed system, the mixer supports efficient blending of buffers, media, and other process components. Its free-floating impeller design promotes uniform mixing without compromising product integrity, even under high solid-load conditions.

Designed for scalability, Avantor Magnetic Mixer systems support volumes from 0.5 L for early-stage development to 1500 L for production scales, with extended options up to 2500 L. These systems enable seamless process monitoring and control through integrated features such as double-jacketed vessels for precise temperature control, load cells for process monitoring and weight control, bag inflation assist and single-use sensors for pH, conductivity and dissolved oxygen measurement. The user-friendly integrated HMI offers recipe creation and automation through OPC U/A connectivity. Ease of use is prioritize by the standardization of the control interface across all systems negating the need for retraining when using different mixer sizes.

The data presented below illustrates the dissolution behavior of a model solute (NaCl) across multiple vessel sizes when operated at defined impeller speeds and power densities. By combining advanced engineering with intuitive operation, the Avantor Magnetic Mixer system empowers biopharmaceutical manufacturers to achieve reproducibility, maintain sterility, and optimize operational efficiency at every stage of production.

COMPARATIVE OVERVIEW OF MAGNETIC MIXING SYSTEM SIZES

Avantor Magnetic Mixer systems deliver a unified, intuitive experience across sizes, pairing the same touchscreen control and automation features with purpose-built hardware for each scale. Smaller units, designed for volumes as low as 0.5 to 20 L, feature compact skids and smaller impellers that enable fast, responsive mixing ideal for development work. Large scale systems spanning maximum volumes of 50 L to 1500 L and beyond employ larger impellers in a clean, compact design across standard and configured option solutions, bringing robust, production-ready performance to high-volume operations. **Table 1** provides detailed specifications of each magnetic mixer system model.

One of the key advantages of Avantor Magnetic Mixer systems is the standardized control interface across all configurations, as shown in **Figure 1**. Whether operating a 10 L development unit or a 1500 L production system, the same intuitive touchscreen layout ensures a familiar experience for every operator. This consistency eliminates the need for re-training when scaling up, reduces the risk of user error, and streamlines process transitions. By keeping controls simple and uniform, Avantor makes scalability effortless and helps teams maintain efficiency and confidence at every stage of production.

Bag Size (l)	Skid Dimensions (h x l x w, mm)	Max RPM	Recommended Max RPM	Impeller Diameter (mm)	Power Number	Min Mixing Volume (L)	Configuration Options	
							Single-use Sensors	Other
5	447 x 260 x 473	5000	5000	27	1,93	0,4	pH	LC* DJ**
10	447 x 260 x 473	5000	5000	27	1,93	0,4	pH	LC* DJ**
20	515 x 325 x 538	5000	5000	27	1,93	2	pH	LC* DJ**
50	1175 x 932 x 600	1100	500	110	2,32	5	pH, DO, Cond	LC, DJ, BI, C
100	1177 x 1232 x 707	1100	1000	110	2,32	20	pH, DO, Cond	LC, DJ, BI, C
200	1177 x 1232 x 707	1100	1000	110	2,32	20	pH, DO, Cond	LC, DJ, BI, C
500	1287 x 1612 x 887	1100	1100	110	2,32	50	pH, DO, Cond.	LC, DJ, BI, C
1000	1706 x 1622 x 1087	1100	1100	110	2,32	100	pH, DO, Cond	LC, DJ, BI, C
1500	1996 x 1722 x 1167	1100	1100	110	2,32	150	pH, DO, Cond	LC, DJ, BI, C

Note: All mixers are equipped with temperature sensors, * Standard **Custom accessory
DO: Dissolved Oxygen Cond: Conductivity LC: Loadcells DJ: Double jacket BI: Bag inflation Assist C: Integrated Chiller

TABLE 1: Avantor Magnetic Mixer systems scale from development to production. The progression in size and design across different volumes enable compact, high-speed systems for small batches to transition into robust, large-scale configurations for manufacturing.

FIGURE 1: The Avantor Magnetic Mixer system touchscreen interface is designed for simplicity and consistency across all mixer sizes. The unified layout provides clear visibility of key parameters such as rpm, temperature, pH, conductivity, and scale weight, along with intuitive controls for manual operation and timers. By maintaining the same interface from development to production systems, operators can easily transition between scales without additional training, reducing complexity and improving process efficiency.

SOLIDS-LIQUIDS MIXING PERFORMANCE OF AVANTOR MAGNETIC MIXER SYSTEMS

Efficient mixing of solids into liquids is a critical step in biopharmaceutical buffer preparation and media formulation. Poor mixing can lead to inconsistent concentrations, extended processing times, and operational inefficiencies. To evaluate the scalability and robustness of the Avantor Magnetic Mixer system technology, two complementary studies were conducted using NaCl as a model solute.

The first study assessed mixing performance across 10 L, 50 L, 200 L, 1500 L volumes while creating a 1 M NaCl solution. The second study challenged the system with creating a high-concentration 5 M NaCl solution by adding all of the salt at once, simulating a worst-case scenario. Together, these studies evaluate NaCl dissolution behavior across multiple magnetic mixer sizes, from benchtop to manufacturing scale, under selected operation conditions.

In this section, results are presented in terms of power density to enable comparison of dissolution times across vessels operating at different impeller speeds. Power density is the specific mixing power per unit volume and is calculated using the formula below, where P is the mechanical power (W) delivered to the fluid, and V is the volume (m^3).

$$\text{Power Density} = \frac{P}{V}$$

For mixing systems, P (W) can be calculated from the dimensionless power number NP using the formula below, where ρ is the fluid density of the solution (kg/m^3), N is the rotational speed (rev/s), and D is the impeller diameter (m). This approach allows direct conversion from rpm to power density. Representative conversions used in these studies are summarized in **Table 2**.

$$P = N_P * \rho * N^3 * D^5$$

These results highlight the Avantor Magnetic Mixer system's ability to combine speed, scalability, and process control in a single-use, low-shear environment. By maintaining consistent performance across volumes even under challenging conditions, the system enables seamless scale-up and supports modern biopharmaceutical manufacturing where efficiency and reproducibility are critical.

Volume (L)	rpm	Power Density (W/m^3)
10	2000	102
10	4500	1168
50	400	221
50	700	1186
100	400	111
100	800	885
200	500	108
200	1100	1151
1500	950	98
1500	1100	153

TABLE 2: Representative conversions of impeller speed (rpm) to power density (W/m^3) for Avantor Magnetic Mixer systems at max working volume in multiple vessel sizes.

Study 1: Typical Buffer Preparation (1 M NaCl) [1,2]

In the first study, Avantor Magnetic Mixer systems at four scales (10 L, 50 L, 200 L, and 1500 L) were filled to approximately 90% of their working volume with water. The mixing system was brought to the desired impeller speed before solid NaCl was introduced to achieve a 1 M NaCl solution. Conductivity probes were positioned at the top center and bottom corner to monitor dissolution progress. Final mixing time was defined as conductivity stabilization within ± 5 percent of the target value **(Figure 2)**.

The study shows that NaCl dissolution time decreases with increasing impeller speed and that dissolution times fall within similar ranges across vessel sizes when evaluated at comparable power densities **(Figure 3)**. In the first study, dissolution of NaCl occurred in less than three minutes at a power density of approximately 1200 W/m^3, which is close to the maximum power density for the systems, regardless of vessel size **(Figure 4)**. At lower power densities, mixing times are expectedly longer due to slower circulation, but even under these conditions all systems including the 1500 L mixer achieved complete dissolution in under 6 minutes **(Figure 5)**. Together, these results showcase that mixing times decreases with increasing impeller speed, consistent with expected mixing behavior.

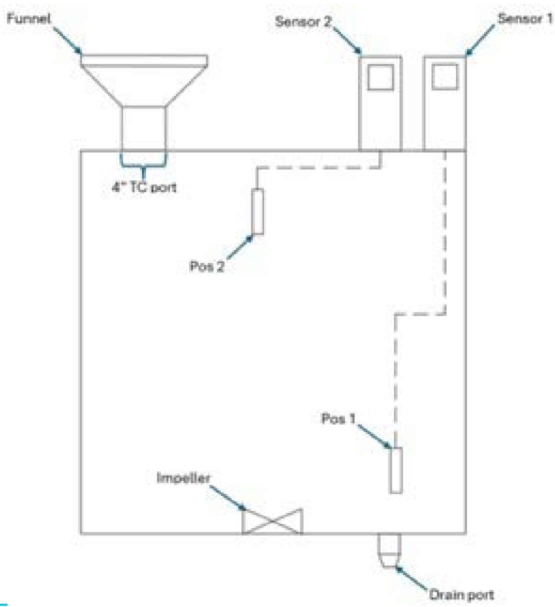

FIGURE 2: The schematic shows a single-use Avantor Magnetic Mixer system bag, represented by the square figure, and the experimental set up for the mixing system used for the solid–liquid NaCl dissolution tests. Sodium chloride was added through a funnel connected to a 4-inch TC port while the impeller was running. Two conductivity sensors were positioned at distinct locations: Pos 1 (bottom region near the drain port) and Pos 2 (mid-height). The sensors were used to monitor mixing performance and endpoint stability.

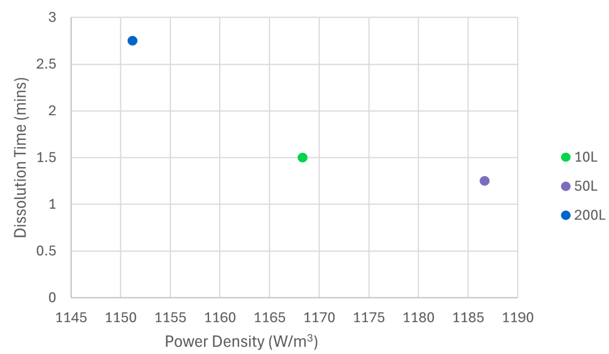

FIGURE 4: Dissolution time versus power density for Avantor Magnetic Mixer system across 10 L, 50 L, and 200 L vessels at approximately 1200 W/m^3.

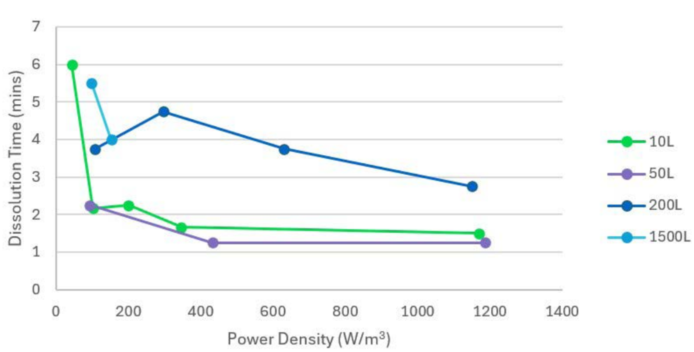

FIGURE 3: Power density vs. mixing time to acheive 1 M NaCl across 10 L, 50 L, 200 L, 1500 L volumes.

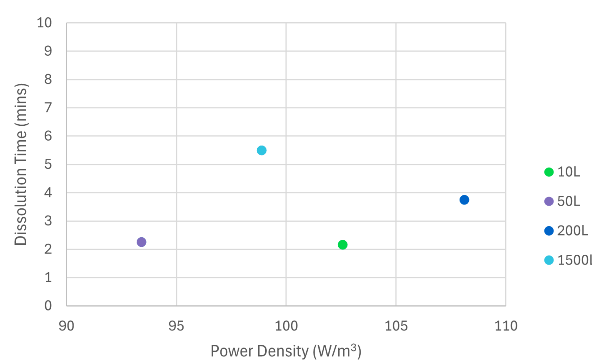

FIGURE 5: Dissolution time plotted against power density for 10 L, 50 L, 200 L, and 1500 L systems demonstrate strong scalability. At comparable power densities (approximately 95–110 W/m^3), all volumes achieve complete mixing in under 6 minutes, showing how consistently each system responds under matched conditions.

Study 2: High-Concentration Salt Mixing (5 M NaCl) [3]

To simulate a high-solids loading scenario, a large amount of NaCl was added all at once to generate a 5 M solution. All evaluations were conducted at different rpm ranges for 50 L, 100 L, and 200 L systems. Conductivity was monitored continuously, in a set up similar to **Figure 2**, to determine the time required for complete dissolution and stabilization.

Even when a large amount of NaCl was added all at once, Avantor Magnetic Mixer system achieved rapid dissolution across all tested scales. At lower power densities near 110 W/m^3, dissolution only required 8 to 9 minutes to reach homogeneity. As power density increased toward the 850 W/m^3 to 900 W/m^3 range, dissolution times dropped to under 2 minutes for all volumes. Whether operating at 50 L, 100 L, or 200 L, the mixer delivers nearly the same dissolution behavior, turning high load buffer prep into a fast and reliable operation **(Figure 6)**.

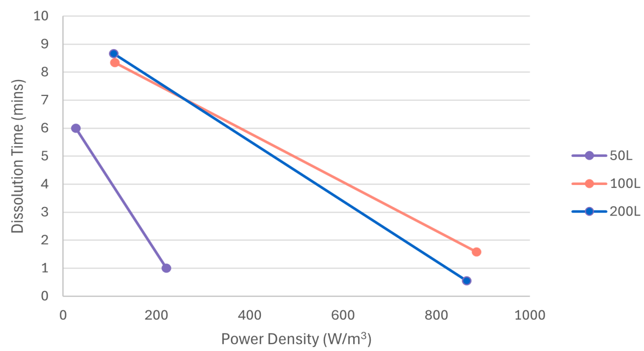

FIGURE 6: Power density versus mixing time for 50 L, 100 L, and 200 L during high-solids loading to achieve a 5 M NaCl.

CONCLUSION

The Avantor Magnetic Mixer system evaluated in this study showed comparable NaCl dissolution behavior across several vessel size when assessed under selected operating conditions.

Each system is designed to fit seamlessly into modern single-use workflows, with integrated sensing, precise control, supported by design features that make it practical for both development and production environments. The mixing platforms demonstrate a clear combination of thoughtful engineering, consistent performance, and practical usability across tests of all sizes.

The comparative overview shows how each mixing system size is purposefully designed, with geometry, drive capability, and instrumentation tuned to the needs of its volume. The standardized control interface keeps operation simple and familiar. This shared platform makes it straightforward for teams to transition between volumes without retraining or adjusting established workflows.

The solids-liquids mixing studies reinforce this consistency in real applications. Both NaCl experiments show that dissolution behavior tracks closely across vessels, even under high load conditions. Mixing times measured at equivalent power densities show similar values across the evaluated vessel scales. These results indicate comparable system performance during buffer preparation.

Together, these findings suggest that power density may serve as a useful parameter for comparing NaCl dissolution behavior across different magnetic mixer sizes from bench top to large scale manufacturing. These results are specific to the test conitions and model system evaluated in this study.

REFERENCE

1. Evaluation of solid–liquid mixing performance and scalability of Avantor Magnetic Mixer systems (10 L, 50 L, and 200 L), assessing solid dissolution behavior and mixing efficiency under standardized test conditions. Data on file, Avantor Magnetic Mixer Solid–Liquids Technical Report, Avantor Biopharma Applications Laboratory, Bridgewater, NJ, August 2025
2. Add a footnote: Solid–liquid mixing characterization of the 1500 L Avantor Magnetic Mixer system evaluating dissolution performance and bulk mixing efficiency. Data on file, Test Nr. T043 02 RD MMS, Avantor Tilburg Applications Laboratory, September 2025.
3. Solid–liquid mixing performance assessment of Avantor Magnetic Mixer systems (50 L, 100 L, and 200 L) evaluating dissolution behavior and mixing efficiency. Data on file, Test Nr. TLB ENGG RD 033 1, Avantor Tilburg Applications Laboratory, June 2023.