

# Sparger in Bioreactor

A practical guide to sparger in bioreactor, covering the reader intent, the relationship to sparger in bioreactor, key evaluation criteria, common risks, and the information the intended project audience should confirm before taking the next step.



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In industrial bioprocessing, the efficiency of a biological reaction is often limited by the rate at which oxygen or other gases can be transferred into the liquid medium. The sparger in bioreactor systems serves as the critical interface for this gas-liquid mass transfer. As a specialized component designed to introduce gas into the culture medium, the sparger's design directly influences bubble size, gas distribution, and the overall oxygen transfer coefficient (KLa).

For engineers and procurement teams, selecting the correct sparger involves balancing the need for high mass transfer rates with the physical constraints of the biological system, such as shear sensitivity of cells and the requirement for rigorous sterilization. This article examines the technical specifications, material considerations, and engineering principles behind sparger selection in industrial bioreactors.

## | The Role of Sparging in Mass Transfer

The primary function of a sparger in bioreactor applications is to provide sufficient dissolved oxygen (DO) to support aerobic respiration in microbial or mammalian cell cultures. In some cases, spargers are also used to introduce carbon dioxide for pH control or nitrogen for stripping unwanted gases.

## | Oxygen Transfer Rate (OTR)

The Oxygen Transfer Rate is governed by the equation:

$$\text{OTR} = KLa (C - CL)$$

Where KLa is the volumetric mass transfer coefficient, C is the saturated dissolved oxygen concentration, and CL is the actual dissolved oxygen concentration in the broth.

Since C and CL are largely determined by the process temperature, pressure, and biological demand, the sparger's primary role is to maximize the KLa. The KLa is influenced by two main factors: the liquid-side mass transfer coefficient (kl) and the specific surface area (a). By producing smaller bubbles, a sparger increases the total surface area available for gas exchange per unit volume of gas, thereby enhancing the "a" component of the equation.

## | Types of Spargers in Industrial Bioreactors

Sparger designs vary based on the required bubble size and the nature of the biological culture. Choosing between different types requires an understanding of the trade-offs between mass transfer efficiency and operational complexity.

### | 1. Sintered Metal Spargers (Micro-spargers)

Sintered metal spargers, often manufactured from stainless steel powder, are utilized when high mass transfer efficiency is paramount. These components feature a porous structure that creates millions of tiny bubbles, typically in the range of 10 to 100 microns.

**Advantages:** Extremely high surface-area-to-volume ratio, which is ideal for high-density cultures or shear-sensitive mammalian cells that require low gas flow rates.

**Considerations:** Due to the fine pore structure, these spargers are more susceptible to fouling or clogging if the medium contains high concentrations of solids or if cleaning protocols are insufficient.

### | 2. Ring Spargers

A ring sparger consists of a circular tube with several drilled holes (orifices). It is usually positioned at the bottom of the bioreactor, below the lowest impeller. The gas exits through the holes, and the impeller's shear forces break the large bubbles into smaller ones.

**Advantages:** Robust design, easy to clean, and low pressure drop.

**Considerations:** The initial bubble size is much larger than that of a sintered sparger, making the system highly dependent on the agitator speed to achieve adequate mass transfer.

## | 3. Pipe and Nozzle Spargers

These are the simplest forms, consisting of a single open pipe or a nozzle. They are primarily used in very large-scale fermentations where clogging is a significant risk or where the agitation system is powerful enough to handle the primary dispersion of gas.

## | Engineering and Material Selection

In the pharmaceutical and food industries, material integrity is non-negotiable. The sparger in bioreactor environments must withstand harsh chemical cleaning and high-temperature sterilization without leaching contaminants into the product.

## | Stainless Steel 316L

Stainless steel 316L is the industry standard for bioreactor internals. Its low carbon content and the addition of molybdenum provide excellent resistance to pitting and corrosion, especially when exposed to the salts and organic acids found in culture media. Furthermore, 316L is fully compatible with Steam-in-Place (SIP) and Clean-in-Place (CIP) cycles.

## | Pore Size and Porosity

For sintered spargers, the pore size (measured in microns) determines the initial bubble diameter. Engineers must specify the pore size based on the gas flow rate (vvm - volume of gas per volume of liquid per minute) and the viscosity of the medium. A more uniform pore distribution ensures that gas does not "channel" through a single path, which would lead to large bubbles and reduced efficiency.

## | Technical Challenges: Shear Stress vs. Mass Transfer

A critical consideration in sparger design is the impact of bubble behavior on cell viability. When bubbles rise through the medium and eventually burst at the surface, they generate significant shear forces.

1. **Mammalian Cell Cultures:** These cells lack a rigid cell wall and are highly sensitive to shear. Micro-spargers are often preferred here because they provide the necessary oxygen at lower gas velocities, reducing the frequency of bubble-bursting events at the surface.
2. **Microbial Fermentation:** Bacteria and yeast are generally more robust. In these applications, ring spargers combined with high-speed agitation are common, as the cells can withstand the mechanical energy required to break up larger bubbles.

## | Installation and Positioning

The physical placement of the sparger in bioreactor vessels is essential for optimizing gas holdup—the volume fraction of gas in the liquid.

**Sub-Impeller Placement:** Most spargers are located directly beneath the agitator. This ensures that the gas stream is immediately intercepted by the impeller blades, facilitating radial distribution and preventing gas from rising in a narrow column (chimney effect).

**Clearance:** There must be sufficient clearance between the sparger and the vessel bottom to prevent stagnant zones, yet it must be close enough to the impeller to maximize the power input for bubble breakage.

## | Maintenance and Cleaning Protocols

To maintain consistent performance, spargers must be part of a rigorous maintenance schedule. Over time, proteins, cellular debris, and mineral deposits can accumulate on the sparger surface or within the pores of sintered elements.

**CIP/SIP:** Standard cleaning involves alkaline and acidic washes followed by high-pressure steam sterilization. For sintered metal spargers, the internal pressure during CIP must be managed to ensure the cleaning solution penetrates the pores.

**Ultrasonic Cleaning:** For removable sintered spargers, periodic ultrasonic cleaning in a detergent bath is the most effective way to remove deeply embedded particulates that standard CIP might miss.

**Integrity Testing:** In regulated environments, spargers may undergo pressure-hold tests or bubble-point tests to ensure that the porous structure has not been compromised by mechanical stress or corrosion.

## | Customization and OEM Requirements

Every bioprocess has unique requirements based on the vessel geometry and the biological characteristics of the culture. Off-the-shelf spargers may not provide the optimal KLa or may create dead zones in custom-designed tanks.

Customization options typically include:

**Tailored Pore Sizes:** Adjusting the micron rating to match specific gas flow requirements.

**Custom Fitting and Geometries:** Designing the sparger to fit unique vessel shapes or to integrate with existing piping manifolds.

**Surface Finishes:** Electropolishing the stainless steel surfaces to minimize protein adhesion and improve the effectiveness of CIP cycles.

For organizations looking to optimize their filtration and gas distribution systems, working with an experienced manufacturer is essential. Detailed information on custom metal filtration components and industrial solutions can be found by visiting the [Main Page](#).

## | Conclusion

The sparger in bioreactor systems is far more than a simple gas inlet; it is a precision-engineered component that dictates the limits of biological productivity. Whether utilizing the high-efficiency micro-bubbles of a sintered metal sparger or the robust simplicity of a ring sparger, engineers must prioritize material quality, pore uniformity, and cleanability. By selecting 316L stainless steel components and tailoring the design to the specific needs of the cell line, manufacturers can ensure reliable mass transfer, minimize cell damage, and maintain the stringent hygiene standards required in modern biotechnology.