LPCs for Precision Parts Cleaning

Ensuring Cleanliness Standards and Product Quality

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Overview

Parts Cleaning for the aerospace, automotive, data storage, medical devices, microelectronics, and semiconductor industries is a highly specialized process involving various advanced techniques and stringent standards.

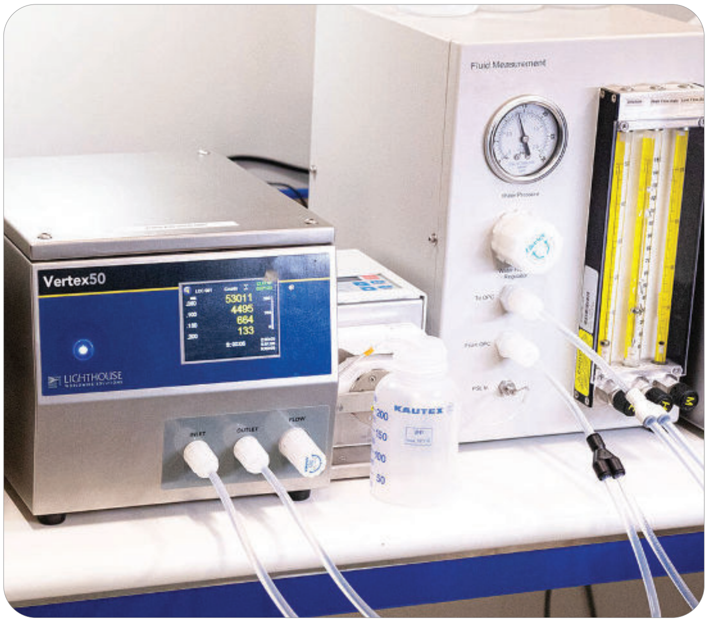
Contamination on the surfaces of electronic components and mechanical assemblies can significantly impair performance as well as reduce production yields, and shorten the lifespan of products. Medical Devices, particularly class III medical devices – such as implants, require that the products are free from particle contamination; which could be detrimental to the patient's cardiovascular system health. To mitigate these risks, manufacturers have implemented stringent cleaning procedures to ensure that precision components are free of contaminants which could negatively impact the final product.

Additionally, environmental regulations have increasingly restricted the use of many traditional cleaning solvents – due to their ecological impact. As a result manufacturers have shifted towards water-based cleaning methods, often enhanced with surfactants. While these methods effectively remove a variety of contaminants, particulate contamination remains a critical concern.

The use of liquid particle counters has become a standard practice for monitoring particulate contamination of precision parts in real-time. These devices continuously measure the concentration of particles in the cleaning solution, providing immediate feedback on the effectiveness of the cleaning process. This real-time monitoring helps ensure that parts are thoroughly cleaned and meet required standards for cleanliness, thus preventing potential failures, safety or performance issues in the final product.

Liquid Particle Counter technology has greatly improved over the years and inline continuous monitoring can get down to true sensitivity levels of 50nm as seen with the Vertex50.

By adopting these advanced cleaning and monitoring technologies, manufacturers can maintain high-quality standards while complying with environmental regulations.



LWS Vertex50 real-time inline liquid particle counter with a sensitivity of 50nm.

Here is an overview of some common parts cleaning methodologies and practices used across various industries.

Ultrasonic Cleaning

This method uses high-frequency sound waves to agitate a cleaning solution, high-frequency sound waves create cavitation bubbles in a cleaning solution. These bubbles implode to remove contaminants from surfaces, effectively removing contaminants from complex parts with threads, rough surfaces, or blind interior spots. It is widely used for delicate and intricate components in both semiconductor and aerospace industries.

Industries: Semiconductor, Aerospace, Medical Devices, Automotive, Data Storage, Microelectronics.

Validation: Liquid Particle Counters: Measure the number and size of particles in the cleaning solution to ensure cleanliness levels meet industry standards

Immersion Cleaning

Parts are submerged in a solvent or aqueous solution, which dissolves contaminants. This method is often combined with ultrasonic cleaning to enhance the cleaning efficacy for parts with complex geometries. High-velocity turbulence is generated with jet manifolds to create a consistent, turbulent flow that agitates and removes product residue from process parts.

Industries: Semiconductor, Aerospace, Medical Devices, Automotive, Microelectronics.

Validation: Liquid Particle Counters: Measure particle levels in the cleaning solution before and after the process to ensure thorough cleaning.

CO_2 Cleaning

Uses carbon dioxide in solid (dry ice) or liquid form to clean parts, which sublimate or impinge to remove contaminants.

Industries: Semiconductor, Medical Devices, Aerospace, Data Storage, Microelectronics.

Validation: Liquid Particle Counters: Ensure that no particles are left in the solution or on the parts, validating the cleaning efficacy.

Passivation

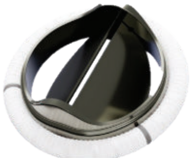
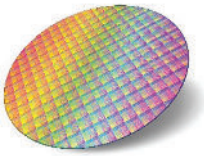
Removes ferrous contaminants from stainless steel parts to improve corrosion resistance. Often follows **ASTM A380** and **A967 standards**.

Industries: Aerospace, Medical Devices

Validation: Liquid Particle Counters: Used to verify that particles are effectively removed during the passivation process.

Examples of Products

requiring specialized parts cleaning techniques

Industry	Example Part	Part Type
Aerospace		Optical Sensors
Automotive		Fuel Injectors
Data Storage		Hard Disk Drive Components
Medical Device		Heart Valves
Semiconductor		Silicon Wafers

What Standards are followed by Industry?

Standards Titles are linked. Click/Tap to learn more >

Aerospace

- **AMS 2700**: Standard for passivation of corrosion-resistant steels.
- **AMS-QQ-P-35**: Standard for passivation treatments for corrosion-resistant steel.
- **ASTM A380**: Standard practice for cleaning, descaling, and passivation of stainless steel parts, equipment, and systems.
- **MIL-STD-1246**: Standard for product cleanliness levels and contamination control program.

Automotive

- **ISO 16232**: Standard for road vehicles—cleanliness of components of fluid circuits.
- **VDA 19.1**: Standard for inspection of technical cleanliness—particulate contamination of functionally relevant automotive components.

General Industry and Microelectronics

- **ASTM E595**: Standard test method for total mass loss and collected volatile condensable materials from outgassing in a vacuum environment.
- **ASTM F312**: Standard practice for cleaning methods and cleanliness levels for materials and equipment used in oxygen-enriched environments.
- **ASTM F331**: Standard guide for cleaning and cleanliness of materials and equipment used in oxygen-enriched environments.

Medical Devices

- **ISO 13485**: Standard for quality management systems for medical devices.
- **ASTM E2314**: Standard test method for determination of particulate contamination of surfaces in healthcare settings.

Semiconductor

- **SEMI F19**: Guide for particle contamination monitoring techniques for gases and gas distribution systems.
- **IEST-STD-CC1246**: Standard for the specification and evaluation of cleanliness levels for materials and equipment.
- **ASTM F311**: Standard practice for cleaning methods and cleanliness levels for material and equipment used in oxygen-enriched environments.

If you'd like to learn more, scan the QR code to visit our Knowledge Center

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How do LPCs work?

Example of a remote 100nm liquid particle counter used to monitor continuously in real time.

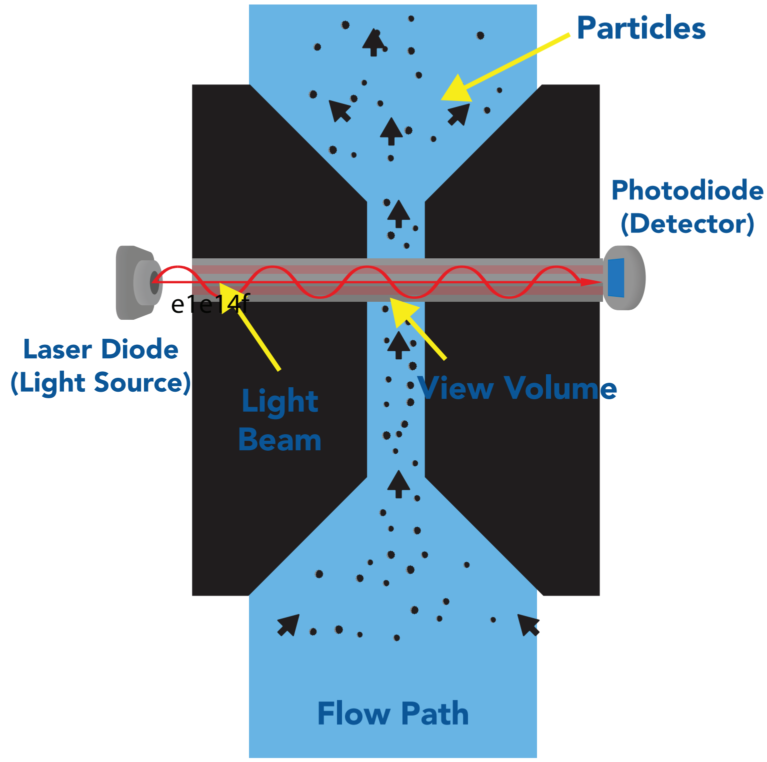
Working Principle of Liquid Particle Counters

The fundamental principle behind LPCs is the interaction of light with particles in the liquid. LPCs typically employ one or more of the following methods to detect particles:

Light Scattering LPC Sensor:

When a particle passes through a beam of light (usually a laser), it scatters light in different directions. The amount and angle of scattered light depend on the particle's size, shape, and refractive index. Photodetectors positioned at specific angles capture this scattered light and generate electrical signals proportional to the particle size.

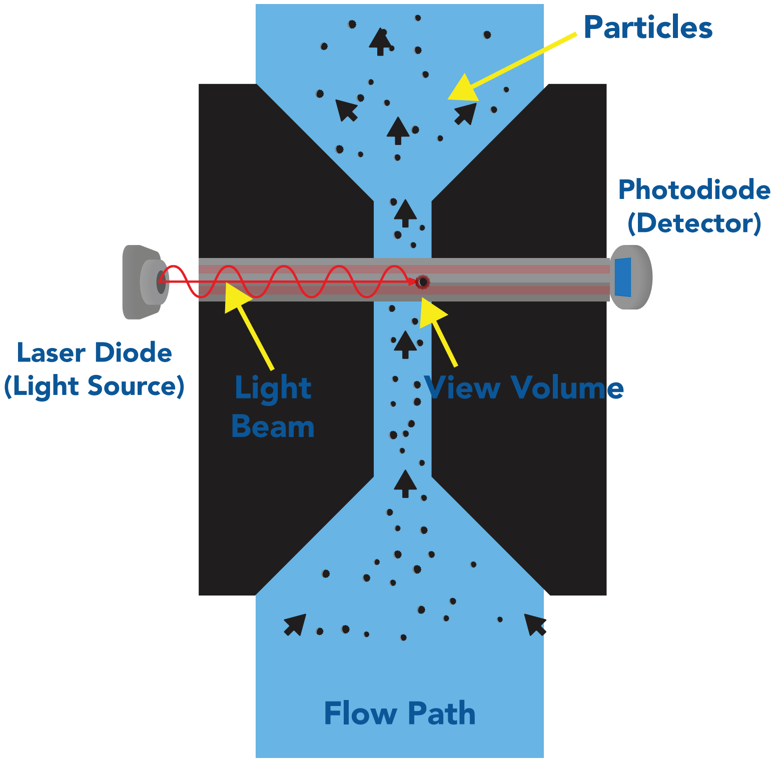
Light scattering Liquid Particle Counters (LPCs) are capable of detecting a broader range of particle sizes compared to light blocking LPCs, thanks to their sensitivity to a wide array of scattering phenomena. The size range they can detect typically depends on the specific design and technology of the instrument, but generally, they can detect particles as small as 0.05 micrometers (µm) and as large as 100 micrometers (µm) or more.



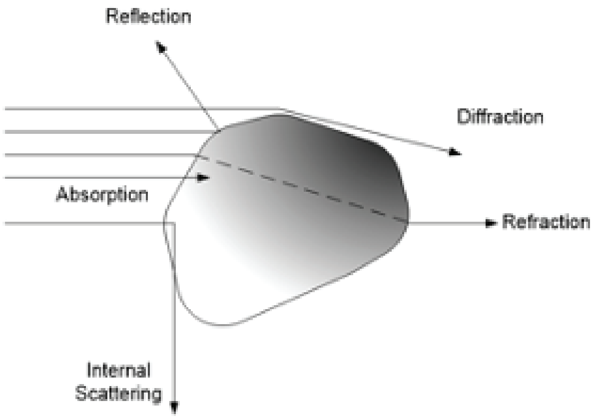
Light Blocking (Extinction) LPC Sensor:

Also known as the light obscuration method, this technique measures the reduction in light intensity as particles pass through a laser beam. Larger particles block more light, causing a more significant reduction in detected light intensity. This change is used to determine the size and concentration of particles.

The limiting size range of a light blocking Liquid Particle Counter (LPC) sensor depends on the specific design and technology used in the instrument. Generally, light blocking or light obscuration LPCs are effective for detecting particles in the size range of approximately 2 micrometers (μm) to 100 micrometers (μm).



Interaction of Light with Particles



The interaction of light with particles involves several phenomena, including refraction, diffraction, reflection, and scattering. These interactions are key to understanding how LPCs detect and measure particles:

Refraction: When light passes through a particle, it bends due to the change in medium from the liquid to the particle. The extent of bending depends on the refractive index difference between the particle and the surrounding liquid. Refraction can alter the path of light, affecting the detection signal.

Diffraction: Diffraction occurs when light waves encounter the edges of a particle, causing the light to spread out. This spreading depends on the wavelength of the light and the size of the particle. Diffraction is particularly significant for particles with sizes comparable to the light wavelength.

Reflection: Some portion of the incident light reflects off the surface of the particle. The amount of reflected light depends on the surface properties of the particle and the angle of incidence. Reflection contributes to the overall light signal detected by the photodetectors.

Light Scattering: Scattering is the redirection of light in different directions after interacting with a particle. There are different types of scattering based on the particle size relative to the wavelength of light:

- **Rayleigh Scattering:** Occurs for particles much smaller than the wavelength of light. The scattered intensity is proportional to the inverse fourth power of the wavelength, causing shorter wavelengths (blue light) to scatter more.

- **Mie Scattering:** Applies to particles with sizes comparable to the wavelength of light. The scattering pattern and intensity are complex and depend on the particle size, shape, and refractive index.

What kind of Parts Cleaning Applications are LPCs used in?

Industry	Parts	Cleaning Methods	Validation Methods	General Particle Size Range
Aerospace	Turbine Blades and Engine Components	Ultrasonic, High-Pressure Spray, Vacuum Bakeout	LPC, Microscopic Analysis, NVR Analysis	>2 microns
	Hydraulic Systems and Actuation Components	High-Pressure Spray, Immersion, Ultrasonic	LPC, Gravimetric Analysis	
	Landing Gear Components	Ultrasonic, High-Pressure Spray, Immersion	LPC, Visual Inspection	
	Fasteners and Tubing	Ultrasonic, CO_2	LPC, Microscopic Analysis	
	Avionics and Electronic Components	Ultrasonic, CO_2	Surface Tension Measurement, TOC Analysis	
	Fuel System Components	Immersion, Ultrasonic	LPC, Microscopic Analysis	
	Optical and Sensor Components	CO_2, Ultrasonic	LPC, Microscopic Analysis	
	Additive Manufactured Parts	Ultrasonic, CO_2	LPC, Microscopic Analysis	
Medical Devices	Surgical Instruments and Implants	Ultrasonic, Immersion, CO_2	LPC, Microscopic Analysis, NVR Analysis	>10 microns
	Diagnostic Equipment Components	Ultrasonic, Solvent-Based	Surface Tension Measurement, TOC Analysis	
	Catheters and Tubing	Immersion, Ultrasonic, Solvent	LPC, Visual Inspection	
	Endoscopes and Flexible Devices	Ultrasonic, High-Pressure Spray	Microscopic Analysis, TOC Analysis	
Automotive	Fuel Injectors and Fuel System Components	Ultrasonic, High-Pressure Spray	LPC, Gravimetric Analysis	>2 microns
	Transmission and Engine Parts	Immersion, Ultrasonic, Solvent	LPC, Microscopic Analysis	
	Brake Components	High-Pressure Spray, Ultrasonic	LPC, Visual Inspection	
	Electronic Control Units (ECUs)	CO_2, Ultrasonic	Surface Tension Measurement, TOC Analysis	
Semiconductor	Silicon Wafers	Ultrasonic, Immersion, CO_2	LPC, Microscopic Analysis, NVR Analysis	< 100nm
	Photomasks	CO_2, Ultrasonic	LPC, Visual Inspection	
	Chip Packaging Components	High-Pressure Spray, Ultrasonic	LPC, Gravimetric Analysis	
Data Storage	Hard Disk Drive Components	Ultrasonic, CO_2	LPC, Microscopic Analysis, NVR Analysis	100nm - 500nm
	Magnetic Heads	Ultrasonic, Solvent	Surface Tension Measurement, TOC Analysis	
	Optical Discs and Drives	CO_2, Ultrasonic	LPC, Visual Inspection	

Importance of LPCs in Parts Cleaning for Cleanroom Industries

Ensuring Compliance Cleanliness Standards

- **Regulatory Requirements:** LPCs help industries comply with stringent cleanliness standards set by regulatory bodies, ensuring that parts meet the required specifications for particulate contamination.
- **Quality Assurance:** By detecting and quantifying particulate contamination, LPCs ensure that parts are cleaned to the highest standards, reducing the risk of non-compliance.

Enhancing Product Quality and Reliability

- **Contamination Control:** LPCs are crucial in identifying and controlling particulate contamination that can compromise product quality, leading to defects or failures.
- **Improved Yield:** Effective parts cleaning verified by LPCs results in higher product yields and fewer rejections or recalls due to contamination issues.

Supporting Process Validation and Optimization

- **Process Monitoring:** LPCs provide real-time data on the cleanliness of parts, enabling continuous monitoring and control of the cleaning processes.
- **Optimization:** Data from LPCs can be used to optimize cleaning processes, ensuring efficient removal of contaminants while minimizing resource use and costs.

Protecting Sensitive Environments and Processes

- **Cleanroom Integrity:** In industries such as pharmaceuticals, microelectronics, and aerospace, maintaining a contaminant-free environment is critical. LPCs help ensure that parts introduced into cleanrooms do not compromise the controlled environment.
- **Preventing Cross-Contamination:** LPCs help prevent cross-contamination by verifying that parts are free from particulates before they enter sensitive manufacturing or assembly areas.

Facilitating Root Cause Analysis and Corrective Actions

- **Identifying Contamination Sources:** LPCs can pinpoint sources of particulate contamination, enabling targeted corrective actions to prevent recurrence.
- **Improving Processes:** By analyzing LPC data, industries can identify weaknesses in their cleaning processes and implement improvements to enhance overall cleanliness and efficiency.

Enhancing Customer Confidence Satisfaction

- **Customer Assurance:** Providing evidence of rigorous parts cleaning through LPC data can enhance customer confidence in the quality and reliability of products.
- **Competitive Advantage:** Demonstrating superior cleanliness standards verified by LPCs can differentiate a company from its competitors, providing a marketing advantage.

Conclusion

Liquid Particle Counters (LPCs) are vital tools in the parts cleaning process for cleanroom industries. They ensure compliance with cleanliness standards, enhance product quality and reliability, support process validation and optimization, protect sensitive environments, facilitate root cause analysis and corrective actions, and enhance customer confidence and satisfaction.

By providing accurate and real-time data on particulate contamination, LPCs play a crucial role in maintaining the high standards required in cleanroom environments.

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Founded in 1982, Lighthouse Worldwide Solutions is the world's leading supplier of real time contamination monitoring systems air samplers and airborne particle counters. The company has leveraged its superior software design, data integration ability and worldwide support offices to provide its customers with leading edge contamination monitoring solutions. These solutions have allowed Lighthouse's customers to maintain high product yields through continuously monitoring conditions that may have an adverse effect on their products. The Lighthouse Monitoring System and Lighthouse line of airborne particle counters have become the standard for many companies, such as Amgen, Genentech, Baxter, Pfizer, Bayer, Novo Nordisk, SpaceX, Tesla, Seagate, TSMC, Samsung, Lockheed Martin, Microchip, Medtronic, 3M, Boston Scientific and many more. www.golighthouse.com