Application Note

Selecting an Airborne-Particle Counter for Your Environment

Abstract

Understanding which features you need in a particle counter is a difficult task. This article will identify the various features available and help you choose which are relevant to your application. The right particle counter will depend on the monitoring environment, communications, monitoring purposes, desired flow rate, and particle size you choose to monitor. Pharmaceutical manufacturing has special monitoring requirements that are not completely addressed here.

Selecting an airborne-particle counter requires some basic understanding of the terminology and procedures of particle counting. All airborne-particle counters sample air at specified volumetric flow rates, which are measured in cubic-feet-per-minute (CFM) or liters-per-minute (lpm). Since particle counters are calibrated at a specific flow rate, the sizing accuracy is dependent upon that flow rate.

To meet most contamination specifications, particle counters must sample defined volumes of air; this provides confidence in the particle data and is often stated as *statistical significance*. The ISO standard requires you to use a specific formula to determine the minimum sample volume. Particle counters with greater flow rates can meet the ISO specifications in less time. A particle counter with a flow rate of 50 lpm can sample one cubic meter in only 20 minutes.

The ISO standards prescribe limits for contamination and the limits can be converted to the obsolete Federal Standard 209E (FS-209E). In most cases the ISO limits are available for common particle sizes such as 0.1, 0.3, and 0.5 microns (µm).

Cleanroom ISO Certification

When the primary application is cleanroom certification, an instrument that has ISO certification features simplifies the process. Modern cleanrooms consistently meet ISO Class 5 or 6 (FS-209E Class 100 or 1000). These cleanroom classifications require the following limits as shown in Table 1.

ISO Classification	Max. Particle Size	Max. Total Particles
5	0.1 µm	100,000
	0.3 µm	10,200
6	0.1 µm	1,000,000
	0.3 µm	102,000

Table 1: Cleanroom Classification Limits

Monitoring a cleanroom in accordance with ISO cleanroom classifications requires the particle counter's specification for maximum concentration to exceed ISO limits. For example, to monitor a Class 5 cleanroom for 0.1 µm particles, the maximum concentration of the counter must be greater than 100,000 particles per cubic meter (2,841 particles per cubic foot). Using a 0.3 µm particle counter to monitor the same Class 5 cleanroom requires a particle counter maximum concentration value of greater than 10,200 particles per cubic meter (290 per cubic foot). These are easily achieved limits with most modern particle counters. Note that there is no ISO specification for 0.1 µm particle counts higher than ISO Class 6, so a 0.1 µm particle counter is not required for those applications.

Particle Size	Flow Rate	Product
0.1 µm	1.0 CFM	LASAIR® II 110
0.3 µm	1.0 CFM	LASAIR II 310
0.5 µm	1.0 CFM	LASAIR II 510
0.5 µm	1.78 CFM	LASAIR II 550L

Table 2: Cleanroom Certifying Solutions

Continuous or Frequent Cleanroom Monitoring

Continuous or frequent monitoring in the cleanroom still needs to demonstrate compliance to ISO.

Frequent monitoring requires sampling at specified time intervals not exceeding 60 minutes during operation. Manifold systems are the least expensive suitable solution and are best installed during cleanroom construction. Stand-alone particle counters may be installed at any time. A manifold system includes either 16 or 32 sampling ports with a single line that connects to a particle counter. The manifold sequentially samples from each port, sends the samples to the particle counter, and then repeats the process. However, since a manifold cycles through many sample points a particle event can go unnoticed if the particle counter is not currently monitoring the appropriate port.

Continuous monitoring requires constant sampling. This method constantly gathers data, so events are not missed. Sample intervals can be any duration, but shorter sample intervals will give better time resolution. Short time intervals, however, provide vast quantities of data that can overwhelm a system. Typical time intervals range from one minute to ten minutes. Particle counter choices for these applications are diverse and plentiful. Factors to consider are particle size, flow rate, and communication options. If a cleanroom has network ports (Ethernet's 10Base-T or 100Base-T), select a particle counter with networking capability. If the cleanroom relies upon serial communications, select a particle counter with RS-232 or RS-485 communication protocols.

Choosing between continuous and frequent cleanroom monitoring is a choice of economics and infrastructure. Dedicated particle counters are the best method to detect particle excursions but at a high cost per sample point. If short-duration events are not critical and the need is for trending then a manifold system can be an effective and economical solution. However, manifold systems cannot reliably transport and count particles much larger than 5 µm.

Frequency	Particle Size	Flow Rate	Communication	Product
Frequent	0.1 µm	1.0 CFM	10Base-T	LASAIR II 110 with AM-II-16 or AM-II-32 Manifold
Continuous	0.2 µm	1.0 CFM	10Base-T	Airnet® 201
Continuous	0.3 µm	1.0 CFM	10Base-T	Airnet 310
Continuous	0.3 µm	0.1 CFM	10Base-T	Airnet 301
Continuous	0.5 µm	1.0 CFM	10Base-T	Airnet 510
Continuous	0.3 µm	0.1 CFM	RS-485	RNet™ 301
Continuous	0.5 µm	1.0 CFM	RS-485	RNet 510

Table 3: Cleanroom Monitoring Solutions

Monitoring Locations

After choosing the type of monitoring method desired, the next step is to determine how many monitoring locations or particle counters are needed. The total number of locations required by ISO can be calculated by determining the area of the cleanroom (in m^2) and finding its square root:

$$N_{locations} = \sqrt{Area(m^2)}$$

Using the formula above and a typical cleanroom area of 9290 m^2 (100,000 $ft.^2$), the square root of 9290 is 96; ISO therefore requires 96 monitoring locations. These locations should be evenly distributed and mounted at work height: 76 cm (30 in.).

Strictly speaking this guideline only applies to cleanroom certification. Cleanroom operators should evaluate their processes and the sensitivity of their product to contamination to determine the number of sampling locations required. Our advice is to monitor where it counts; that is, measure where your product is exposed and where contamination will cause damage. In the case of semiconductor manufacturers that use SMIF pods or FOUPS, the wafers are not exposed to the general cleanroom environment, so monitoring this area is less critical. However, the wafers are exposed in the minienvironment, so monitoring efforts should be focused there. Monitoring should be concentrated where the risk is the highest; in the case of minienvironments, this is often near the load ports where wafers are loaded and unloaded.

Minienvironments

Minienvironments are used to isolate the product from the main source of particles (people) and are often classified as ISO Class 1 or 2 (no FS-209E classification exists for these levels of cleanliness). Within these classifications, most instruments can easily remain under the maximum concentration limits.

ISO Classification	Particle Size	Total Particles	Sample Volume
1	0.1 µm	10	1 m^3
	0.3 µm	---	1 m^3
2	0.1 µm	100	1 m^3
	0.3 µm	10	1 m^3

Table 4: ISO Classification Parameters

Minienvironment particle data often follows trends in differential air pressure, so an instrument's ability to correlate particle and differential pressure data provides trend analysis, yield improvements, and accurately scheduled preventative maintenance cycles. Published minienvironment particle data[1] shows particle concentrations clustered near 0.4 µm, and since the cost of a particle counter doubles as the sensitivity increases from 0.3 µm to 0.1µm, the most cost-effective continuous monitoring solution is a 0.3 µm particle counter with an inclusive differential air pressure (DAP) probe. For validation and certification, a 0.1 µm counter is recommended for ISO class 1 and 2 minienvironments.

Minienvironment Class	Flow Rate	Particle Size	Monitoring Purpose	Product
ISO Class 1 or 2	1.0 CFM	0.1 µm	Validation	LASAIR II 110
ISO Class 1 or 2	1.0 CFM	0.3 µm	Continuous	MiniNet® 310

Table 5: Minienvironment Monitoring Solutions

Filter and Valve Testing

Depending upon the level of accuracy required, testing filters may require specialized particle counters. Aerosol spectrometers employ more than 32 channels for particle size distinction and resolution. Spectrometers provide the most detailed information regarding particle sizes and distributions, but they are expensive.

Standard 0.1 µm or 0.3 µm particle counters can easily monitor filters and valves and are usually installed upstream and downstream of the filter or valve. This technique provides accurate filter efficiency data and alarming for contamination problems, but may not be desirable for testing valves.

Filters use an efficiency rating specified at the most penetrating particle size (MPPS). Standard specifications dictate the filter's efficiency at a specific MPPS and velocity. High Efficiency Particulate Air (HEPA) filters have a minimum filtering efficiency of 99.99% at 0.3 µm, and Ultra Low Penetration Air (ULPA) filters have a minimum filtering efficiency of 99.999% at 0.12 µm. Detecting penetrating particles requires a particle counter with at least 0.3 µm sensitivity for HEPA filter testing and 0.1 µm sensitivity for ULPA filter testing.

Valve testing procedures are outlined by SEMATECH. By their nature, valves tend to trap and shed particles, so sampling particles from a valve can provide unreliable data. Therefore, some of the particles detected may be generated by the process and others may come from the valve, so valve cleanliness reports are difficult to generate.

Filter Type	Particle Size	Flow Rate	Communication	Product
ULPA	0.1 µm	1.0 CFM	10Base-T	LASAIR II 110
HEPA	0.3 µm	1.0 CFM	10Base-T	Airnet 310
HEPA	0.3 µm	0.1 CFM	10Base-T	Airnet 301
HEPA	0.3 µm	0.1 CFM	RS-485	RNet 301
HEPA	0.5 µm	1.0 CFM	RS-485	RNet 510

Table 6: Filter and Valve Monitoring Solutions

Lab Testing

Lab testing applications do not typically need to meet ISO cleanroom requirements. These applications seek a specific number of particle counts within a certain size range, and this number defines whether the lab components will pass or fail. Particle counter selection depends on the components being tested in the lab, so the lab must define the critical particle size limit (in microns) and the acceptable maximum concentration limits.

High flow rates are often desirable as they increase throughput, reduce sampling times, and gather more data. Since lab tests tend to focus upon sub-micron contamination, the choices narrow for particle counters.

Product	Particle Size	Flow Rate
LASAIR II 110	0.1 µm	1.0 CFM
LASAIR II 310	0.3 µm	1.0 CFM
LASAIR II 350L	0.3 µm	1.78 CFM
LASAIR II 510	0.5 µm	1.0 CFM
LASAIR II 550L	0.5 µm	1.78 CFM

Table 7: Lab Testing Solutions

1. *High-yield manufacturing: Particle Monitoring in Minienvironments;* CleanRooms Magazine, April 2004

Harsh Environments

Harsh environments require special instrumentation. These environments may include pharmaceutical labs, cleanroom make-up air handling (MUAH) units, fan decks, or aerospace launch facilities. These conditions require particle counters that are isolated from the environment but still provide accurate air sampling.

Particle counters developed for harsh environments are often housed in NEMA-rated enclosures. These enclosures isolate the sensitive optics and electronics, while providing an external probe for monitoring the particle concentrations.

Pharmaceutical manufacturers are only interested in 0.5 and 5.0 µm particles. Some particle counters offer screen/data configurations that only display/print these specific channels. The LASAIR II 350L and 550L, Airnet series, IsoAir series, and RNet provide this functionality. If a pharmaceutical lab contains heavy concentrations of hydrogen peroxide (H_2O_2), a particle counter with resilient coating and high maximum sampling concentrations, such as the Airnet 510 XR, is recommended.

MUAHs, fan decks, and launch systems require robust enclosures that can withstand harsh conditions. Appropriate particle counters for this use have enclosures made from stainless steel or Kydex®, which provide superior resistance to damaging external conditions but have proven reliability in particle counting. Some of the instruments that meet these conditions include the IsoAir and IsoAir PLUS, the Airnet series, and the RNet.

Product	Particle Size	Flow Rate	Communications	Cover Material
LASAIR II 350L	0.3 µm	1.78 CFM	Ethernet	Kydex
Airnet 310	0.3 µm	1.0 CFM	Ethernet	Kydex
IsoAir 310	0.3 µm	1.0 CFM	Ethernet	Stainless Steel 316L
Airnet 301	0.3 µm	0.1 CFM	Ethernet	Kydex
IsoAir 301	0.3 µm	0.1 CFM	Ethernet	Stainless Steel 316L
IsoAir PLUS	0.3, 0.5 µm	1.0 CFM	Ethernet	Stainless Steel 316L
RNet 301	0.3 µm	0.1 CFM	RS-485	Kydex

Table 8: Harsh Environment Monitoring Solutions

Product	Particle Size	Flow Rate	Communications	Cover Material
LASAIR II 550L	0.5 µm	1.78 CFM	Ethernet	Kydex
Airnet 510 (XR)	0.5 µm	1.0 CFM	Ethernet	Kydex
RNet 510	0.5 µm	1.0 CFM	RS-485	Kydex
IsoAir 550L	0.5 µm	1.78 CFM	Ethernet	Stainless Steel 316L

Table 8: Harsh Environment Monitoring Solutions

Counting Particles in Gases

When choosing a particle counter, you must know if the gas is reactive and its pressure range. Reactive gases include, but are not limited to, hydrogen and oxygen. These gases require a special particle counter stored inside a containment vessel. The containment vessel's design should withstand moderate levels of overpressure, resulting from detonation of mixtures of hydrogen and oxygen. Usually, the containment vessel is back-filled with nitrogen, an inert gas that neutralizes small volumes of reactive gases. It may be possible to monitor other reactive gases, but the user must carefully evaluate the wetted materials of the particle counter to ensure compatibility with the gas. Further, the user should consider additional precautions such as leak monitoring, purge flow monitoring, and any other safety measure to ensure safe operation.

Sampling gases at pressure is preferred, therefore gas instruments employ mass flow controllers to provide constant, volumetric flow rates when connected to gas line pressures between 40-150 psig. Particle sizing can differ with pressure and the composition of gas, so gas particle counters must account for these variables. A gas constant entered into the instrument's data system provides correction factors for different gases and allows the mass flow controller to increase or decrease the flow rate based upon its chemistry.

If the gas is reactive and falls within the specified pressure range, you may sample the gases using Particle Measuring Systems' High-Pressure Gas Probe (HPGP). The HPGP-101-C offers 0.1 µm sensitivity, 0.1 CFM flow rate, and a containment vessel tested to confine an overpressure of 3200 psig.

Non-reactive gases such as argon, helium, neon, nitrogen, and xenon have different monitoring requirements. A dedicated gas particle counter, such as the

Micro Laser Particle Counter (MLPC-101-HP), provides accurate measurements and particle counting in pressurized, non-reactive gases.

Another option for non-reactive gas monitoring is to connect a high-pressure diffuser (HPD) to a stand-alone particle counter. The HPD accommodates pressures from 40-100 psig. The HPD dilutes the gas sample with ambient air, which provides humidity. The humidity prevents degradation of the particle counter's optics and plumbing.

A particle counter combined with an HPD typically has the lowest initial cost. However, monitoring at reduced pressure is not as effective as monitoring at pressure due to several factors:

- potential of particle loss in the diffuser
- smaller percentage of the total gas flow is measured
- the diffuser can become contaminated and cause artificially high particle measurements
- diffuser's design wastes gas that is not measured

Dedicated gas particle counters should be used for critical applications and any measurement of reactive gases. HPDs should be used for less critical applications or for occasional monitoring of non-reactive gases.

Product	Particle Size	Pressure Range	Purpose	Gas Type	Flow Rate
HPGP-101-C	0.1 µm	40-150 psig	Dedicated sampling	Reactive	0.1 CFM
MLPC-101-HP	0.1 µm	40-150 psig	Dedicated sampling	Non-reactive	0.1 CFM
LASAIR II 110 with HPD II-100	0.1 µm	40-100 psig	Dedicated, occasional, or periodic testing	Non-reactive	1.0 CFM
LASAIR II 310 with HPD II-100	0.3 µm	40-100 psig	Dedicated, occasional, or periodic testing	Non-reactive	1.0 CFM

Table 9: Gas Monitoring Solutions

Conclusion

While the purchasing choices may seem endless, recognizing your particular application will help you focus on your requirements. Following the basic guidelines provided in this article, you can purchase the ideal counter to meet your requirements without paying for features you do not need.

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