Selecting an Airborne Particle Counter

Choosing a particle counter depends on various factors such as monitoring environment, communications, desired flowrate, and the particle sizes of interest. This article will identify which features to focus on for your application.

Terminology

All airborne particle counters sample air at a specified volumetric flowrate, which is the speed of the air being pulled through the particle counter. Flowrate units are usually in cubic-feet-per-minute (CFM) or liters-per-minute (LPM). Particle counters are calibrated to sample at their specified flowrates, and sizing accuracy is dependent on that flowrate.

To meet classification standards, particle counters sample defined volumes of air which provide qualifiable, statistical significance to particle count data.

Standards and Certification

A portion of **Table 1** from the ISO 14644-1:2015[1], *Classification for Air Cleanliness by Particle Concentration* standard is provided below. The ISO standards prescribe limits for common sizes of particles such as 0.1, 0.3, and 0.5 µm. Modern cleanrooms consistently meet ISO Class 5 or Class 6 certification.

TABLE 1 Maximum Allowable Particle Concentrations

Classification	Maximum Particle Size	Total Particles	Sample Volume
ISO 5	0.1 µm	100,000	1 m^3
	0.3 µm	10,200	
ISO 6	0.1 µm	1,000,000	
	0.3 µm	102,000	

Source: ISO 14644-1:2015, Table 1.

To meet the ISO 14644-1:2015 standard, a 1 CFM particle counter must sample for 35 minutes to equate to 1 cubic meter. Fast flowrates can achieve ISO specifications in less time. A particle counter with a flowrate of 50 LPM can sample one cubic meter in only 20 minutes.

Monitoring a cleanroom in accordance with ISO cleanroom classifications requires the particle counter's maximum concentration specification 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 particles 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. Solutions to aid in attaining cleanroom certification are listed in Table 2.

TABLE 2 Cleanroom Certifying Solutions

Particle Size	Flowrate	Product
0.1 µm	1.0 CFM	Lasair® III 110 Aerosol Particle Counter
0.3 µm	1.0 CFM	Lasair III 310C Aerosol Particle Counter
0.5 µm	3.56 CFM	Lasair III 5100 Aerosol Particle Counter

FIGURE 1 Lasair III 110 (left) and Lasair III 310C (right)

Frequent or Continuous Cleanroom Monitoring

Frequent Monitoring

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 solution and should be installed during the cleanroom construction process. Standalone 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, 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

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 intervals will also 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.

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 there is a greater need for trending, a manifold system can be an effective and economical solution. However, manifold systems cannot reliably transport and count particles much larger than 5 µm.

Communication Options

If a cleanroom offers network ports (Ethernet 10Base-T or 100Base-T), select a particle counter with networking capability. If the cleanroom relies on serial communications, select a particle counter with RS-232 or RS-485 communication protocols.

FIGURE 2 Airnet® II inside IsoAir® enclosure

TABLE 3 Cleanroom Monitoring Solutions

Frequency	Particle Size	Flowrate	Communication	Product
Frequent	0.1 µm	1.0 CFM	10Base-T	Lasair III 110 with AM II 16/32 Manifold
Continuous	0.2 µm	1.0 CFM	10Base-T	Airnet® II 201 Air Particle Sensor
Continuous	0.3 µm	1.0 CFM	10Base-T	Airnet II 310 Air Particle Sensor
Continuous	0.3 µm	0.1 CFM	10Base-T	Airnet II 301 Air Particle Sensor
Continuous	0.5 µm	1.0 CFM	10Base-T	Airnet II 510 Air Particle Sensor

Monitoring Locations

After choosing the monitoring method, the next step is to determine how many monitoring locations or particle counters are needed. The total number of locations (N_L) required by ISO can be calculated by dividing the area of the cleanroom (in m^2) by 1,000. Then, multiply this number by 27.

$$N_{\mathrm{L}} = 27 \times \left(\frac{A}{1\ 000} \right)$$

Inserting a typical cleanroom area of 9290 m^2 (100,000 ft^2), we can determine the square root is 251. This means ISO requires 251 monitoring locations. These locations should be evenly distributed and mounted at a work height of 76 cm (30 in).

Keep in mind the ISO 14644-1:2015 standard 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. 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 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

To isolate the product from the main source of particles (people), minienvironments are often classified as ISO Class 1 or Class 2. Within these classifications, most instruments can easily remain under the maximum concentration limits.

TABLE 4 Maximum Allowable Particle Concentrations

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

Source: ISO 14644-1:2015, Table 1.

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[2] 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 0.1 µm 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 Class 2 minienvironments.

TABLE 5 Minienvironment Monitoring Solutions				
Minienvironment Class	**Particle Size**	**Flowrate**	**Monitoring Purpose**	**Product**
ISO Class 1 or 2	0.1 µm	1.0 CFM	Validation	Lasair III 110 Aerosol Particle Counter

Filter and Valve Testing

Depending on the level of accuracy required, testing filters may require specialized particle counters. Aerosol spectrometers employ more than thirty-two channels for particle size distinction and resolution. While expensive, spectrometers provide the most detailed information regarding particle sizes and distributions.

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

TABLE 6 Filter and Valve Monitoring Solutions				
Filter Type	**Particle Size**	**Flowrate**	**Communication**	**Product**
ULPA	0.1 µm	1.0 CFM	10Base-T	Lasair III 110
HEPA	0.3 µm	1.0 CFM	10Base-T	Airnet II 310
HEPA	0.3 µm	0.1 CFM	10Base-T	Airnet II 301

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 is dependent on the components being tested in the lab, so the lab must define the critical particle size limit (in µm) 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 focus on sub-micrometer contamination, the choices narrow for particle counters.

TABLE 7 Lab Testing Solutions

Particle Size	Flowrate	Product
0.1 µm	1.0 CFM	Lasair III 110
0.3 µm	1.0 CFM	Lasair III 310C
0.3 µm	1.78 CFM	Lasair III 350L
0.5 µm	3.56 CFM	Lasair III 5100

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 particle concentrations.

Pharmaceutical manufacturers' interests lie only in 0.5 µm and 5.0 µm. Some particle counters offer screen/data configurations that only display/print these specific channels. The Lasair® III 350L and Lasair III 5100, Airnet® II series, and IsoAir® series provide this functionality. If a pharmaceutical lab contains heavy concentrations of hydrogen peroxide H_20_2, a particle counter with resilient counting and high maximum sampling concentrations, such as the Airnet II 510 XR is recommended.

MUAHs, fan decks, and launch systems require robust enclosures that can withstand conditions outside normal room environments. Appropriate particle counters 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 310P and the Airnet II series.

TABLE 8 Harsh Environment Monitoring Solutions

Cover Material	Particle Size	Flowrate	Communication	Product
Stainless Steel 316L	0.1 µm	1.0 CFM	Ethernet	Lasair III 110
Stainless Steel 316L	0.5, 5.0 µm	1.0 CFM	Ethernet	Airnet II 510s, 510s XR
Stainless Steel 316L	0.3, 0.5 µm	1.0 CFM	Ethernet	IsoAir 310P
Polycarbonate	0.3 µm	1.0 CFM	Ethernet	Airnet II 310
Polycarbonate	0.3 µm	0.1 CFM	Ethernet	Airnet II 301
Polycarbonate	0.5 µm	1.0 CFM	Ethernet	Airnet II 510 XR
Polycarbonate	0.3 µm	50 LPM	Ethernet	Lasair III 350L
Polycarbonate	0.5 µm	100 LPM	Ethernet	Lasair III 5100

Counting Particles in Gases

Determine whether the gas is reactive and what pressure range it will have before choosing a particle counter for gases. Examples of reactive gases include 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 from detonation between 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. The user should also 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 flowrates when connected to gas line pressures between 40 - 159 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 flowrate based on the chemistry of the gas.

If the gas is reactive and falls within the specified pressure range, you may sample the gases using a High-Pressure Gas Probe (HPGP). The HPGP-101-C offers 0.1 µm sensitivity, 0.1 CFM flowrate, and a containment vessel to confine overpressures of 3200 psig.

FIGURE 3 HPGP-101-C

Non-reactive gases such as argon, helium, neon, nitrogen, and xenon have different monitoring requirements. The option with the lowest initial cost is connection from a standalone particle counter to a high-pressure diffuser (HPD), which dilutes the gas sample with ambient air and provides humidity. The humidity prevents degradation in a particle counter's optics and plumbing. The HPD III from Particle Measuring Systems accommodates pressures from 40 - 100 psig.

FIGURE 4 Lasair III 310C with HPD III

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 occasional monitoring of non-reactive gases.

TABLE 9 Gas Monitoring Solutions

Gas Type	Purpose	Particle Size	Flowrate	Pressure Range	Product
Reactive	Dedicated sampling	0.1 µm	0.1 CFM	40 - 150 psig	HPGP-101-C
Non-reactive	Dedicated, occasional, or periodic testing	0.1 µm	1.0 CFM	40 - 100 psig	Lasair III 110 with HPD II-100
Non-reactive	Dedicated, occasional, or periodic testing	0.3 µm	1.0 CFM	25 - 100 psig	Lasair III 310C with HPD III

Conclusion

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

References

1. ISO 14644-1, *Cleanrooms and Associated Controlled Environments*. 2015.
2. High-yield manufacturing: Particle Monitoring in Minienvironments; *CleanRooms Magazine*, April 2004.