Airborne particle counting with an LSAPC

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Editor

11.0 Introduction

It is necessary to demonstrate in cleanrooms that the concentration of airborne particles does not exceed that which is acceptable. Chapter 4 gives the table of the maximum airborne particle concentrations for different cleanliness classes of cleanrooms and cleanzones according to ISO 14644-1: 2015 [ref 7]. To ensure that a cleanroom complies with the specified ISO class, it is tested by the method given in ISO 14644-1 which will be explained in the next Chapter 12. It is also necessary to monitor the cleanroom over its lifetime to ensure that the specified airborne particle concentration is not exceeded. This chapter discusses airborne particle counters that are used to carry out these tasks.

Airborne particle counters are referred to in ISO 14644-1: 2015 as 'light scattering airborne particle counters' (LSAPCs). This name distinguishes them from aerosol photometers used to detect leaks of particles in high efficiency air filter installations and are discussed in Chapter 8. An LSAPC sizes and counts the number of individual particles in air, whereas photometers measure the total concentration of particles in air. A typical LSAPC with an isokinetic intake and Wi-Fi aerial is shown in Figure 11.1.

11.1 How does an LSAPC work?

Figure 11.2 shows the main components of an LSAPC. A sample of cleanroom air is drawn into the instrument and passes through the sensing zone. Also passing through the sensing zone is a beam of light, which comes from a laser diode or a helium-neon laser. Single particles passing through the beam will scatter light. This light is collected and directed by an optical system to a photodiode where it is converted into an electrical pulse. The height of the pulse enables the size of particle to be obtained and, by counting the number of pulses, the number of particles is ascertained. Knowing the sampling rate of the LASPC, the concentrations of different sizes of airborne particles are obtained.

The size of a particle is obtained by an LSAPC from the amount of light scattered by the particle. Therefore, it is not its physical size that is measured but its 'equivalent optical size', which is the diameter of a spherical particle that scatters the same amount of light as the particle being measured. The equivalent optical size that is measured by the LSAPC is obtained by calibrating the instrument with standard mono-dispersed particles of polystyrene latex, which are spherical and readily scatter light. Therefore, the correlation between the actual physical dimensions of a particle and its equivalent optical size depends on the substance of which it is composed and its shape.

The range of particle sizes required in the classification of a cleanroom, according to ISO 14644-1: 2015 is between ≥0.1µm and ≥5µm and these sizes can be counted by an LSAPC. However, an LSAPC that only measures particles down to 0.3µm or 0.5µm may be suitable for testing in many types of cleanrooms. LSAPCs are available with airflow sampling rates of 2.8L/min (0.1

Figure 11.1 A typical LSAPC

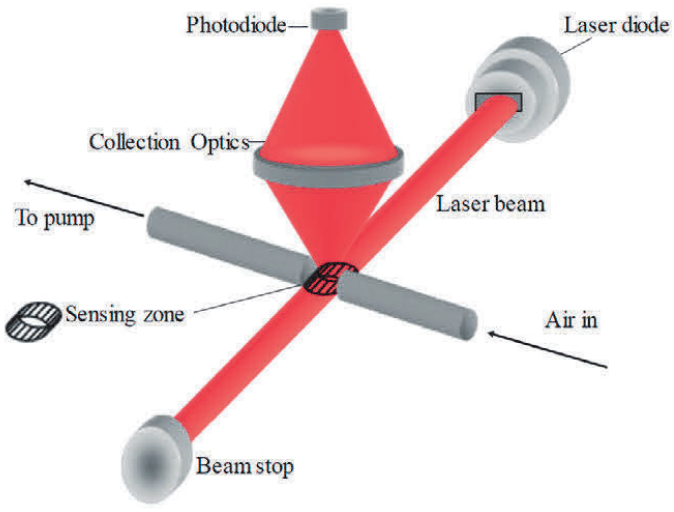

Figure 11.2 Particle detection method used in an LSAPC with the light path shown in red

ft³/min), 28.3L/min (1 ft³/min), 50L/min and 100L/min.

LSAPCs must be regularly serviced and calibrated. The calibration should conform to ISO 21501-4: 2018 [ref 26]. However, ISO 14644-1: 2015 points out that some particle counters cannot be calibrated by use of all of the tests and, if this is the case, this information should be recorded in the test report.

11.2 Cumulative and differential counts

An LSAPC is normally used to count particles that are equal to, or greater than (≥), a specified size of particle. This is known as a 'cumulative' count, and it is this count that is required by the ISO cleanroom standards. However, LSAPCs can also measure 'differential counts', which are counts between given particle sizes, e.g. between ≥0.5µm and ≥1.0µm. Care must be taken to ensure that differential counts are not mistakenly measured when testing cleanrooms.

An example that explains the difference between differential and cumulative counts is given in Table 11.1. Shown in column 1 are the differential size ranges and in column 2 are their particle counts. In column 3 are the cumulative size ranges that correspond to the smallest differential size in each row, and include all particle sizes equal to, and above those sizes. Finally, in column 4, are the cumulative particle counts, which are obtained from an LSAPC, but can also be obtained by adding together all the differential particle counts in column 2 up to the particle size in question.

11.3 Coincidence loss

If the concentration of airborne particles is too high, inaccurate counts may be obtained from an LSAPC because of 'coincidence' losses. These losses can be caused by two or more particles in the light beam being 'seen' by the LSAPC as one large particle. It is also possible that small particles can be hidden behind large ones. ISO 21501- 4: 2018 suggests that the maximum particle concentration that should be sampled is one where the coincidence loss is less than 10% of the total count. This will typically occur in concentrations above $10^6/m^3$ to $10^7/m^3$ but the actual value should be obtained from the manufacturer's literature.

11.4 Diluting an air sample

When high particle concentrations are encountered that cause coincidence loss in an LSAPC, it may be necessary to dilute the airborne particles before they are counted by an LSAPC. If tests are being carried out to (a) measure the decay of particles to obtain the recovery rate, (b) challenge a high efficiency filter installation with particles to measure leaks using an LSAPC, or (c) establish the penetration of particles into clean air devices by the segregation test method, it may be necessary to measure airborne concentrations that are higher than the concentration where coincidence losses occur. Should this be the case, a 'diluter' can be used to remove particles from a portion of the air that is sampled, and thereby reduce the high concentration of airborne particles to a level that can be accurately measured.

Figure 11.3 shows how a diluter works. The air entering the diluter is split into two alternative paths. The minor part of the sampled air passes through a small diameter tube that restricts the airflow without affecting the concentration of particles. The greater part of the sampled air passes though the larger diameter side arm and through a high efficiency air filter that removes all of these particles. The two flows are united and this results in the actual air sample that has passed through the small tube being diluted with particle-free air from the side arm. A variety of diluters are available that give dilution ratios of between about 10: and 1000:1. It is also possible to combine two diluters in series to dilute the particle concentration.

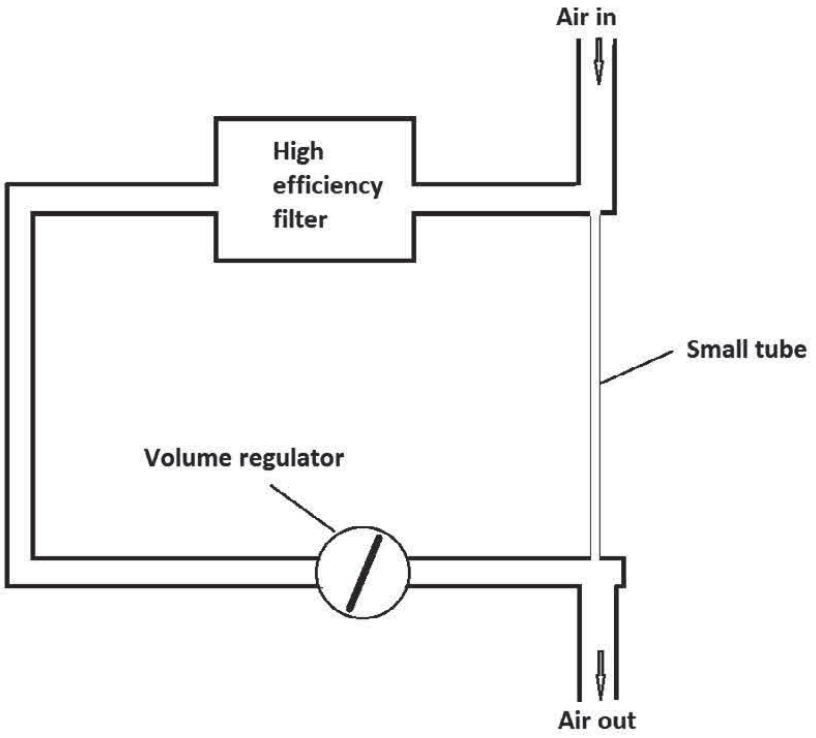

Figure 11.3 Particle diluter

Table 11.1. Differential and cumulative counts from an LSAPC

Differential particle size range	Differential particle count/m³	Cumulative particle size range	Cumulative particle count/m³
≥0.3µm to ≥0.5µm	12,053	≥ 0.3µm	16,276
≥0.5µm to ≥1µm	3,105	≥ 0.5µm	4,223
≥1µm to ≥5µm	1108	≥ 1µm	1118
≥5µm	10	≥5µm	10

11.5 Particle losses during air sampling

When cleanroom air is sampled by an LSAPC, it is necessary to ensure that the LSAPC accurately sizes and counts all of the airborne particles, and none are lost or added. To do this, the following information should be considered. Further information is given in Annex G.

Wall losses in the sampling tube: If the air sampling location is some distance away from the LSAPC, a sampling tube is required to transport the airborne particles to the LSAPC. However, as particles flow along the tube they may deposit onto the inner wall. This loss is mainly caused by larger sizes of particles, which are deposited by gravitational settling. Because of this problem, it is best not to use a sampling tube but, if it must be used, it should be as short as possible. ASTM F50-12 (2015) [ref 27] recommends that sampling tubes should be no longer than 3 metres, and ISO 14644-1: 2015 suggests that for sampling particles ≥1µm, the tube length should not be longer than 1 metre. There can also be particle losses at the bends of a tube owing to the particles being thrown by their inertia onto the inner tube wall, and it is suggested in ASTM F50-12 (2015) that the radius of curvature of the tube should be greater than 15cm.

Particle losses in a sampling tube owing to electrostatic attraction: If the sampling tube possesses an electrostatic charge, then particles can be attracted to the tube's inner wall and deposited. To minimise this loss, the tubing should be a good electrical conductor, such as Bev-A-Line tubing, or tubing made from polyurethane with a conductive additive.

Other sampling tube considerations: The tube to the particle counter should not be knocked or moved during sampling, or particles deposited in the tube may be dislodged. This is especially important if a low concentration of particles is being measured. In addition, the sampling tube should be sealed when not in use, to protect it against particle contamination. Similarly, when not in use the inlet into the LSAPC should be capped to protect it from contamination.

Orientation of sampling probe: To ensure good sampling, the sampling probe should be correctly orientated to the airflow direction. When sampling in unidirectional airflow, the probe inlet should face directly into the unidirectional airflow. In the mixed airflow found in non-UDAF systems, the intake of the tube or probe should face upwards.

Isokinetic sampling: When sampling in unidirectional airflow, isokinetic sampling is required to give the true concentration of the airborne particles. This is unnecessary for small particles around the size of 0.3µm and 0.5µm, as these will not leave the airstream and are not lost by impaction onto intake surfaces. However, if larger macroparticles are sampled, isokinetic sampling is required. Isokinetic and anisokinetic sampling are illustrated in Figure 11.4. It should be noted that, as discussed in the previous paragraph, the sampling probe should be orientated so that the unidirectional air flows parallel to it.

Figure 11.4 (a) shows the situation where the velocity of the air into the probe is the same as the air passing it. This is known as isokinetic sampling. When isokinetic sampling is used, the air flows smoothly into the probe and particles are neither lost nor gained. In Figure 11.4 (b), the air velocity into the probe is greater than outside it and the airflow is anisokinetic. As shown in the figure, particles with sufficient size and inertia will not flow with the air but are thrown outside of the probe and not sampled. The air sample will therefore have a lower concentration of large particles than the actual concentration in the air being sampled. Shown in Figure 11.4 (c) is a probe in which the air velocity into the probe is less than that outside it. The streamlines of the expected airflow are shown. As the air turns away from the probe, particles with sufficient inertia will be thrown into the probe and the air sample will have a higher concentration of large particles than the actual concentration in the air being sampled.

It is usually impossible to provide isokinetic sampling in non-UDAF cleanroom as the air flows in a variety of directions and at different velocities, but to obtain the best sample, the probe should face upwards. However, an isokinetic probe may be used to provide a sharp entrance at the air intake and reduce particle deposition caused by a blunt intake.

If attention is paid to the information given in this chapter, an accurate count

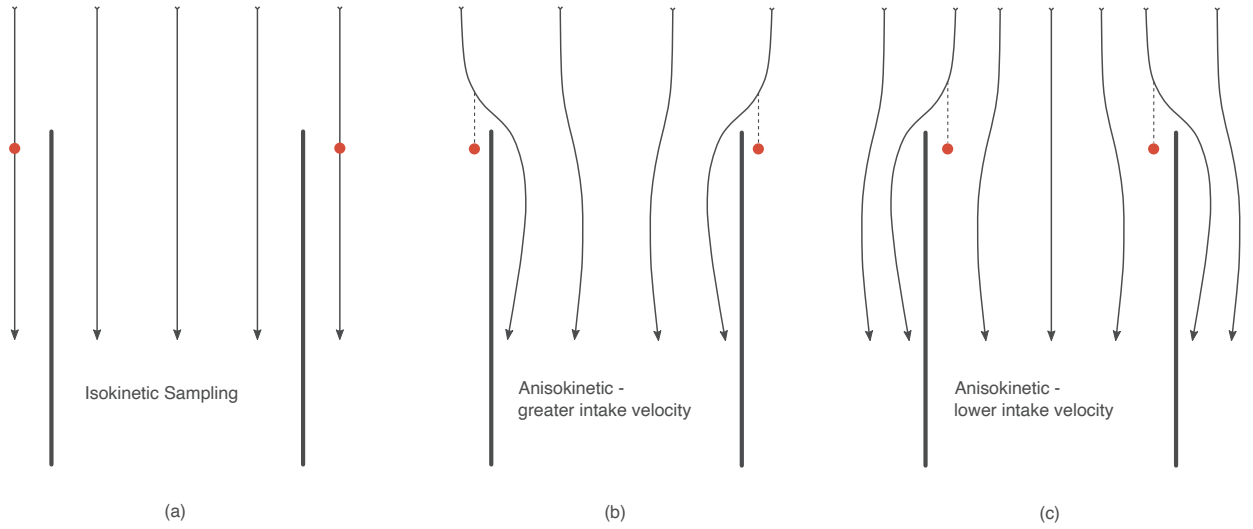

Figure 11.4 Isokinetic and anisokinetic sampling

of the specified sizes of particles in sampled air should be obtained. This ensures that the cleanliness classification of a cleanroom or clean zone will be correct. The classification method given in ISO 14644-1: 2015 will be discussed in the next Chapter 12.

Acknowledgements

The LSAPC shown in Figure 11.1 is reproduced by permission of Particle Measuring Systems. Bob Latimer kindly drew Figure 11.2.

References (numbered as at the end of the book)

[7] ISO 14644-1:2015 – Part 1: Classification of air cleanliness by particle concentration. International Organization for Standardization, Geneva, Switzerland.

[26] ISO 21501-4:2018. Determination of particle size distribution – Single particle light interaction methods – Part 4: Light scattering airborne particle counter for clean spaces. International Organization for Standardization, Geneva, Switzerland.

[27] ASTM F50-12 (2015). Standard practice for continuous sizing and counting of airborne particles in dust-controlled areas and cleanrooms using instruments capable of detecting single sub-micrometer and larger particles. ASTM International, West Conshohocken, PA, USA.

Dr William (Bill) Whyte is an Honorary Research Fellow at Glasgow University and has the useful dual qualifications of a BSc in microbiology and a DSc in mechanical engineering. He has been involved in the design, testing, and operation, of cleanrooms and hospital operating rooms for over 50 years.

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