New Standard on Macro-Particles and Visible Particles in Cleanrooms—ISO 14644-17, Particle deposition rate applications

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Abstract

ISO TC 209 has developed a series of standards for cleanrooms and associated controlled environments. To date, 19 ISO 14644 and 14698 standards have been published. With respect to particles, the focus has been on airborne particles up to 5 micrometers. In many applications, larger particles--even visible particles--need to be controlled. ISO 14644-17 'Particle deposition rate applications' provides guidance on the control of macroparticles. Background information with a personal view is given. The new standard offers control tools for many industries.

Introduction

A cleanroom or an associated controlled environment is used to limit contamination of vulnerable surfaces by particles or microbe-carrying particles. Classified cleanrooms do not predict the expected surface contamination by particles; although the likelihood of surface contamination is reduced as the class of the cleanroom in operation is increased. In ISO 14644-3:2019 'Test Methods' Annex B10, the measurement of a particle deposition rate is described. However, no information is given on the application of particle deposition rate.

Particle deposition rate is determined by air cleanliness during operation. The air cleanliness is determined by the cleanroom installation and cleanroom use. The particle deposition rate provides information on the quality of the operations programs in a cleanroom. The new standard can be used to set requirements, to establish control, and to demonstrate control by monitoring the particle deposition rate. In cases where the particle deposition rate is higher than expected by the established cleanroom class, a review of the cleanroom operation may be needed.

Particle Deposition Rate

A particle deposition rate determines the change of surface cleanliness with respect to particles during exposure. Since particles deposit from the air onto a surface, the particle deposition rate is affected by air cleanliness. The deposition of particles depends on their concentration in the air and their deposition velocity. The deposition velocity is the combination of the sedimentation velocity and the local air movement. Turbulent air flows can increase the deposition velocity. The sedimentation velocity depends on the size of the particle and the specific density. In cleanrooms, the majority of the particles are emitted by personnel. In most cases, the average density is about 1,200 kg/m^3. The deposition velocity depends on particle size and increases with the square of the particle size. One can calculate the sedimentation velocity using Stokes' law. In a cleanroom, it is useful to determine the cumulative sedimentation velocity which depends on the particle size distribution [1]. In general, the number of particles is reciprocally proportional to the particle size. Table 1 below identifies the deposition velocity for some particle sizes and the corresponding measured cumulative deposition velocities in an ISO 8 cleanroom.

Table 1: Deposition velocities of particles

Equivalent aerodynamic particle diameter (µm)	**Deposition velocity (cm/s) of particles with discrete diameters**	**Deposition velocity (cm/s) of particles with cumulative diameters**
5	0.09	0.29
10	0.36	0.91
25	2.3	4.2
40	5.8	9.1
50	9.0	13
100	29	41

One can observe a particle in an air pocket. If this pocket leaves the cleanroom before a particle can leave the air pocket by deposition, it will be removed from the cleanroom. This means that particle deposition is influenced by the residence time of an air pocket in the cleanroom. This residence time is influenced by the local air change rate, which depends on the air supply per m^2, the cleanroom height, and the ventilation effectiveness [2].

The most important operational aspects are garment use, entry procedures, cleaning programs, and processing methods.

The particle deposition rate (R_D) is expressed as the number of particles ≥D µm per square meter per hour. In general, the number of particles is reciprocally proportional to the particle size. The particle deposition rate level (L) gives the deposition rate of the equivalent number of particles ≥10 μm per m^2·h. The particle deposition rate levels are given in order of magnitudes from L = 1 to L = 1,000,000.

Need for the New Standard

Particle deposition is observed during operation in cleanrooms where people are working. Personnel generates, carries, and distributes particles of all sizes. Most particles up to approximately 25 micrometers can be removed by air flow. The air cleanliness with respect to particles ≥25 μm is difficult to determine directly.

An air cleanliness level does not give direct information on the likelihood of product contamination. A particle deposition rate gives a relation between airborne particle concentration and the likelihood of product surface contamination. The expected number of critical particles equals the particle deposition rate for these critical particles times the product area times the time of exposure.

Both aspects were the supporting reasons for this standard. Since the measurement method is already described in ISO 14644-3:2019, the title of ISO 14644-17:2021 is 'Particle deposition rate applications.' In contamination control cleanliness, requirements can be derived from an impact assessment. Required product cleanliness levels are input for the particle deposition rate control to be established. In operation, the effectiveness of the control can be demonstrated by monitoring the particle deposition rate.

In some applications, like optical systems, it is not the number of particles that is important, but rather the obscuration or area coverage. The area coverage is the sum of the cross-section areas of the deposited particles relative to the observed area. The obscuration rate is the change of the particle area coverage during exposure and can be applied in a similar way as the particle deposition rate to determine the expected surface contamination [3].

Measurement of Particle Deposition Rate

Particle deposition rate can also be expressed as the change of surface cleanliness in number of particles larger than or equal to the smallest measured particle size per surface area during exposure. The surface concentration can be recalculated to the particle size of interest by multiplying the concentration with the observed particle size and dividing by the particle size of interest.

Particle deposition rates can be measured using witness plates and measuring the surface cleanliness before and after exposure and determining the time of exposure in the associated state of occupancy. Instruments to measure a particle deposition rate using dedicated witness plates are available. Instruments with a built-in test surface can measure the change of surface cleanliness with short intervals and can be used as real time particle deposition monitors [4].

Particle Deposition Rate Limit

The maximum acceptable contamination, in number of particles larger than or equal to a critical particle size on a critical surface, is determined by the particle deposition rate during exposure. By determining the vulnerable area, the time of exposure, and the maximum number of critical particles, the limit for the particle deposition rate can be determined. For particles up to almost 40 micrometer an empirical relation is given with the air cleanliness for particles ≥5 µm per m^3 during operation. In combination with the intended use, this can be used as requirement for the cleanroom installation.

Particle deposition can increase in the concentration of particles on surfaces. Surface particles can be transferred onto other surfaces during contact. The deposition of larger particles can be reduced by proper operational programs. The personnel entry program should limit the introduction of particles and the cleaning program should remove surface particles frequently to keep the surface cleanliness within a given limit. Guidance is given in ISO 14644-5 'Operations.'

Establish Control for a Particle Deposition Rate Limit

To establish air cleanliness control, ISO 14644-4:2022 'Design, construction and startup' can be used. To manage energy consumption, ISO 14644-16:2019 'Energy efficiency in cleanrooms and clean air devices' can be applied. The intended operation should be considered in the design and should include the facilities to implement the operations programs.

Demonstrate Control by Monitoring Particle Deposition Rate

By monitoring the particle deposition rate, the control can be implemented. In case the particle deposition rate is too high, the particle size distribution provides information on the type of improvements that can be made. An example in an ISO 6 cleanroom is given in Figure 1.

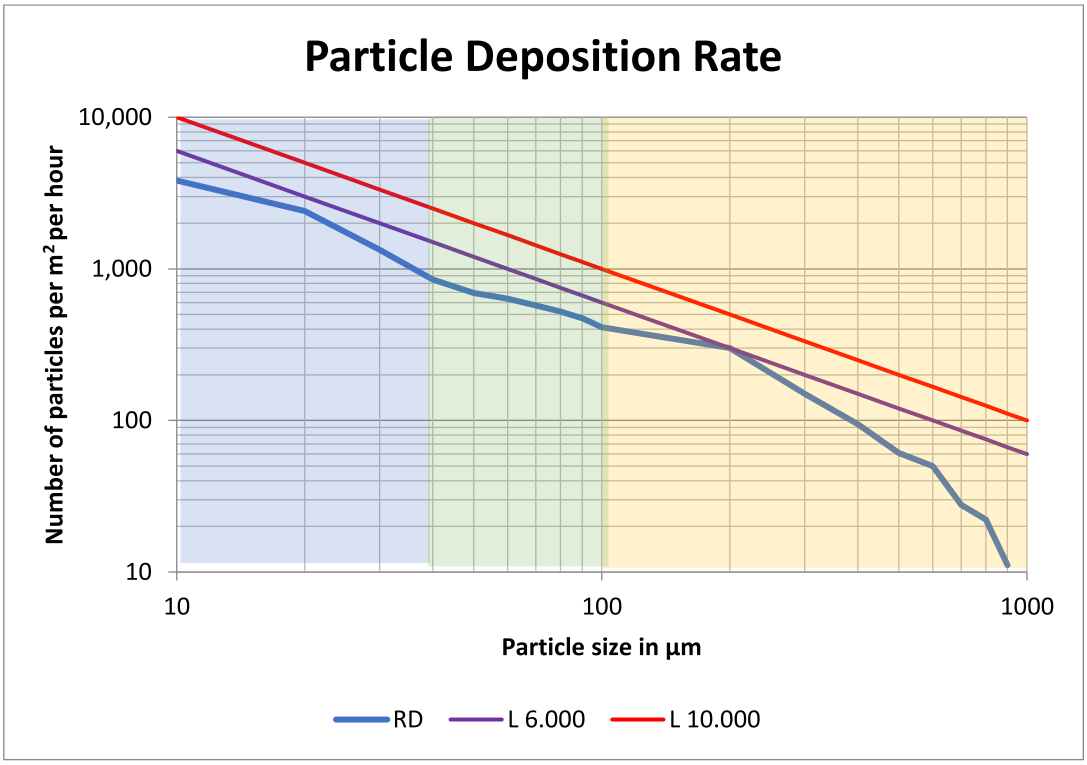

Figure 1. Cumulative particle deposition rate R_D distribution with PDR Level lines

If the particle deposition rate of particles > 100 um is too high, the cleaning program and its execution should be reviewed. In case the particle deposition rate for particles ≥ 40 µm to ≥100 µm is too high, the personnel discipline should be reviewed.

Real time particle deposition monitoring data can be used to find potential sources.

Conclusion

This new standard is useful for products that are sensitive to macro particles and visible particles in cleanrooms.

Industries that could be impacted by particle deposition rates include aerospace, automotive, batteries, medical devices, optical system, displays, electronics, and others.

Bibliography

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About the Author

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He is active in education and standards for cleanroom technology. He is secretary of the Technical Committee of the ICCCS (International Confederation of Contamination Control Societies). He is expert in ISO TC209 and CEN TC243 and the development of the ISO 14644 standards. He has been secretary of the ICCCS, treasurer and chairman of the CTCB-I (International Cleanroom Testing and Certification Board) and secretary and treasurer of the VCCN (Netherlands Contamination Control Society).

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