



Designation: ~~F50-07~~ Designation: F50 - 12

# Standard Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometre and Larger Particles<sup>1</sup>

This standard is issued under the fixed designation F50; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers the determination of the particle concentration, by number, and the size distribution of airborne particles in dust-controlled areas and clean rooms, for particles in the size range of approximately 0.01 to 5.0  $\mu\text{m}$ . Particle concentrations not exceeding  $3.5 \times 10^6$  particles/ $\text{m}^3$  (100 000/ $\text{ft}^3$ ) are covered for all particles equal to and larger than the minimum size measured.

1.2 This practice uses an airborne single particle counting device (SPC) whose operation is based on measuring the signal produced by an individual particle passing through the sensing zone. The signal must be directly or indirectly related to particle size.

NOTE 1—The SPC type is not specified here. The SPC can be a conventional optical particle counter (OPC), an aerodynamic particle sizer, a condensation nucleus counter (CNC) operating in conjunction with a diffusion battery or differential mobility analyzer, or any other device capable of counting and sizing single particles in the size range of concern and of sampling in a cleanroom environment.

1.3 Individuals performing tests in accordance with this practice shall be trained in use of the SPC and shall understand its operation.

1.4 Since the concentration and the particle size distribution of airborne particles are subject to continuous variations, the choice of sampling probe configuration, locations and sampling times will affect sampling results. Further, the differences in the physical measurement, electronic and sample handling systems between the various SPCs and the differences in physical properties of the various particles being measured can contribute to variations in the test results. These differences should be recognized and minimized by using a standard method of primary calibration and by minimizing variability of sample acquisition procedures.

1.5 Sample acquisition procedures and equipment may be selected for specific applications based on varying cleanroom class levels. Firm requirements for these selections are beyond the scope of this practice; however, sampling practices shall be stated that take into account potential spatial and statistical variations of suspended particles in clean rooms.

NOTE 2—General references to cleanroom classifications follow Federal Standard 209E, latest revision. Where airborne particles are to be characterized in dust-controlled areas that do not meet these classifications, the latest revision of the pertinent specification for these areas shall be used.

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1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards statements, see Section 8.

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

D1356 [Terminology Relating to Sampling and Analysis of Atmospheres](#)

F328 [Practice for Calibration of an Airborne Particle Counter Using Monodisperse Spherical Particles](#)

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee E21 on Space Simulation and Applications of Space Technology and is the direct responsibility of Subcommittee E21.05 on Contamination.

Current edition approved Nov. 1, 2007. Published November 2007. Originally approved in 1965. Last previous edition approved in 2001 as F50-92(2001)- $\epsilon$ 1. DOI: 10.1520/F0050-07.

Current edition approved April 1, 2012. Published May 2012. Originally approved in 1965. Last previous edition approved in 2007 as F50-07. DOI: 10.1520/F0050-12.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

F649 [Practice for Secondary Calibration of Airborne Particle Counter Using Comparison Procedures](#)

F658 [Practice for Calibration of a Liquid-Borne Particle Counter Using an Optical System Based Upon Light Extinction](#)

2.2 *U.S. Federal Standard:*

Federal Standard No. 209E, Clean Room and Work Station Requirements, Controlled Environment<sup>3,4</sup>

2.3 *Other Documents:*<sup>5</sup>

ISO 14644-1 Cleanrooms and Associated Controlled Environments, Classification of air cleanliness

ISO 14644-2 Cleanrooms and Associated Controlled Environments, Specifications for testing and monitoring to prove continued compliance with ISO 14644-1

### 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *dust-controlled area*—a clean room or clean work space in which airborne and deposited particulate contamination levels, or both, are controlled on the basis of a documented standard such as Federal Standard 209E.

3.1.2 *dynamic range*—the particle size range, expressed as a multiple of the minimum measured size, over which the SPC can measure particles with size resolution of 10 % or less.

3.1.3 *particle concentration*—the number of individual particles per unit volume of ambient temperature and pressure air, particles/m<sup>3</sup> or particles/ft<sup>3</sup>.

3.1.4 *particle size*—equivalent diameter of a particle detected by an SPC.

3.1.4.1 *Discussion*—The equivalent diameter is the diameter of a reference sphere of known size and physical characteristics (for example, refractive index when using an OPC; density when using an aerodynamic particle sizer; etc) and generating the same response in the SPC sensing zone as the particle being measured. Spherical particles are used for calibration of the SPCs considered here. The SPC response is related to the size, shape, orientation and physical properties of the particle passing through the SPC sensing zone. If an optical particle counter is used, the geometry of the optical system, as well as the spectral distribution of the illuminating light influences the reported particle size. If a condensation nucleus counter with a size-fractionation device is used, the SPC operating parameters and the particle properties that affect the nucleation efficiency and, for example, the diffusion coefficient, will influence reported data. The SPC instruction manual should make the user aware of the effects of such factors on the indicated particle size data.

3.1.5 *primary calibration*—calibration with standard reference particles for particle size and (optionally) concentration. Initially carried out by the SPC manufacturer.

3.1.6 *resolution*—the capability of the SPC to differentiate between particles with small difference in size.

3.1.6.1 *Discussion*—It can be quantified as the ratio of the square root of the difference between the measured and actual variances of a monosized particle size distribution to the mean diameter of those monosize particles, using procedures as shown in Practice F658.

3.1.7 *standardization*—secondary calibration of electronic system voltage and signal response threshold levels using the reference system built into the SPC.

3.1.7.1 *Discussion*—The SPC should be capable of carrying out this procedure with a simple, rapid manual operation or by internal timed or microprocessor controlled components.

3.2 For definitions of other terms used in this practice, see Terminology D1356 and (Federal Standard 209E).

### 4. Summary of Practice

4.1 Satisfactory primary calibration within the manufacturer's recommended time period and routine standardization should be verified as a first step.

4.2 A sample acquisition program is established on the basis of the cleanliness level that is to be verified or monitored. This program will include sample point identification, sample size definitions and sampling frequency, specification of the sampler inlet and sample transport system, definition of the particle size ranges to be measured, and any other parameters of concern in the dust-controlled area or clean room.

4.3 Air samples are passed through the SPC and the particle content of each sample is defined by the SPC. Particles contained in the sampled air pass through the sensing zone of the SPC. Each particle produces a signal that can be related to particle size. An electronic system sorts and counts the pulses, registering the number of particles of various sizes that have passed through the sensing zone during passage of a known gas volume. The concentration and particle size data can be displayed, printed or otherwise processed, locally or remotely.

<sup>3</sup> Available from U.S. General Services Administration, Federal Supply Service, Standardization Division, Washington, DC 20406, <http://www.gsa.gov>.

<sup>4</sup> Fed-Std-209E has been replaced by ISO/DIS 14644-1 and -2, but may continue to be used by mutual agreement.

<sup>5</sup> Available from IEST, 940 E. Northwest Highway, Mt. Prospect, IL 60056 and the International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

<sup>5</sup> Available from Institute of Environmental Sciences and Technology (IEST), Arlington Place One, 2340 S. Arlington Heights Rd., Suite 100, Arlington Heights, IL 60005-4516, <http://www.iest.org>, and from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, <http://www.iso.org>.

## 5. Significance and Use

5.1 The primary purpose of this practice is to describe a procedure for collecting near real-time data on airborne particle concentration and size distribution in clean areas as indicated by single particle counting techniques. Implementation of some government and industry specifications requires acquisition of particle size and concentration data using an SPC.

5.2 The processing requirements of many products manufactured in a clean room involves environmental cleanliness levels so low that a single particle counter with capability for detecting very small particles is required to characterize clean room air. Real-time information on concentration of airborne particles in size ranges from less than 0.1  $\mu\text{m}$  to 5  $\mu\text{m}$  and greater can be obtained only with an SPC. Definition of particles larger than approximately 0.05  $\mu\text{m}$  may be carried out with direct measurement of light scattering from individual particles; other techniques may be required for smaller particles, such as preliminary growth by condensation before particle measurement.

5.3 Particle size data are referenced to the particle system used to calibrate the SPC. Differences in detection, electronic and sample handling systems among the various SPCs may contribute to differences in particle characterization. Care must be exercised in attempting to compare data from particles that vary significantly in composition or shape from the calibration base material. Variations may also occur between instruments using similar particle sensing systems with different operating parameters. These effects should be recognized and minimized by using standard methods for SPC calibration and operation.

5.4 In applying this practice, the fundamental assumption is made that the particles in the sample passing through the SPC are representative of the particles in the entire dust-controlled area being analyzed. Care is required that good sampling procedures are used and that no artifacts are produced at any point in the sample handling and analysis process; these precautions are necessary both in verification and in operation of the SPC.

## 6. Interferences

6.1 Since the SPC is typically a high sensitivity device, its response may be affected by internally or externally generated noise. The SPC should not be operated at a sensitivity level so high that internal noise produces more than 5 % of the data signals.

6.2 Precautions should also be taken to ensure that the test area environment does not exceed the radio frequency or electromagnetic interference capabilities of the SPC.

6.3 Operation at acceptably low levels of internal noise can be verified by drawing a sample into the SPC through a filter or other gas cleaning device that will positively remove at least 99.97 % of all particles of size equal to and greater than that which the SPC will measure. After a short stabilization period, any signals reported by the SPC can be assumed to arise from internal or external noise sources.

## 7. Apparatus

7.1 *SPC*—The apparatus shall consist of a SPC, selected on the basis of its ability to count and size single particles in the required size range. The SPC shall include a sample air flow system, a particle characterization system, and a data processing system. The minimum measurable particle size shall be selected from the clean area definition stated in ISO 14644-1 (Table I of Federal Standard 209E), or from a different specification of clean-area airborne particle concentration at a stated minimum particle size. For classification levels based on measurement of particles larger than 0.05  $\mu\text{m}$ , an optical particle counter (OPC), an aerodynamic particle sizer or an equivalent SPC can be used. For classification levels based on particles less than 0.05  $\mu\text{m}$ , a CNC in combination with a diffusion battery, a differential mobility analyzer or an equivalent SPC can be used.

7.1.1 *Sample Air Flow System*, consists of an intake tube, the particle sensing/measurement chamber, an air flow metering or control system, and an exhaust system. No abrupt transitions in dimension should occur within the air flow system. The inlet tube should consist of a sharp-edged inlet nozzle connected to a tube that will transport the sample air to the particle characterization system. The sample inlet nozzle should have a cross-sectional area equivalent to that of a circle of diameter at least 2 mm. The nozzle can be attached to a transit tube with dimensions so that residence time in the tube will not exceed 10 s. Sample tubes should be configured so that the flow Reynolds number is maintained in the range 5 000 to 25 000. For particles in the size range 0.1  $\mu\text{m}$  to  $\approx 2 \mu\text{m}$  in diameter and a SPC flow rate of 0.028  $\text{m}^3/\text{min}$  (1  $\text{ft}^3/\text{min}$ ), a transit tube up to 30 m long can be used. For particles in the size range  $\approx 2 \mu\text{m}$  to 10  $\mu\text{m}$ , a maximum transit tube length of 3 m can be used. If a flexible transit tube is to be used, then no radius of curvature below 15 cm shall be used.

7.1.2 *Particle Sensing/Measurement Chamber*—Defined by the nature of the SPC that is used. It should be verified that minimum recirculation and recounting of particles occurs in that chamber. If the particle characterization system includes any particle manipulation (for example, diffusion battery or nucleation chamber, etc) before particle sensing occurs, then the SPC element that manipulates the particles shall not result in significant particle number change during that process.

7.1.3 *Air Flow Metering of Control System*, shall be located after the particle sensing/measurement chamber so as to minimize particle losses or artifact generation before measurement occurs.

7.1.4 *Exhaust System*, may consist of either a built-in vacuum source or an external vacuum supply. If the built-in vacuum source is used, then the exhaust stream from that source shall be suitably filtered so that particles sampled by and internally generated by the SPC, or both, are not returned to the dust-controlled area.

7.2 *Particle Characterization System*, shall be capable of both detecting and sizing the particles that are sampled by the SPC. The characterization system particle sizing resolution, expressed as a percentage, shall not exceed 10 % over the operating dynamic range. The SPC specifications shall include information as to the maximum particle concentration that can be measured before