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FEDERAL STANDARD

CLEAN ROOM AND WORK STATION

REQUIREMENTS, CONTROLLED ENVIRONMENT

This standard is approved by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal Agencies.

FSC 3694

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GLOSSARY

1. Scope and limitations.

1.1 Scope. This document establishes standard classes of air cleanliness for airborne particulate levels in cleanrooms and clean zones. It prescribes methods for class verification and monitoring of air cleanliness. It also addresses certain other factors, but only as they affect control of airborne particulate contamination.

1.2 Limitations. The requirements of this document do not apply to equipment or supplies for use within cleanrooms or clean zones. Except for size classification and population, this document is not intended to characterize the physical, chemical, radiological, or viable nature of airborne particulate contamination. No definitive relationship between airborne particulate cleanliness classifications and the level of viable airborne particles has been established. In addition to the need for a clean air supply monitored for total particulate contamination and meeting established limits, special requirements are necessary for monitoring and controlling microbial contamination.

2. Referenced document.

For further information on Student's t, see: Johnson, Norman L. and Leone, Fred C., Statistics and Experimental Design in Engineering and the Physical Sciences, Volume I (New York, London, Sydney: John Wiley & Sons, Inc., 1964).

3. Definitions.

3.1 Airborne particulate cleanliness class. The statistically allowable number of particles equal to or larger than 0.5 micrometer in size per cubic foot of air.

3.2 Calibration. Comparison of a measurement standard or instrument of unknown accuracy with another standard or instrument of known accuracy to detect, correlate, report, or eliminate by adjustment any variation in the accuracy of the unknown standard or instrument.

3.3 <u>Clean zone.</u> A defined space in which the concentration of airborne particles is controlled to specified limits.

3.4 <u>Cleanroom.</u> A room in which the concentration of airborne particles is controlled to specified limits.

3.4.1 <u>As-built cleanroom (facility).</u> A cleanroom (facility) that is complete and ready for operation, with all services connected and functional, but without production equipment or personnel within the facility.

3.4.2 <u>At-rest cleanroom (facility).</u> A cleanroom (facility) that is complete and has the production equipment installed and operating, but without personnel within the facility.

3.4.3 <u>Operational cleanroom (facility).</u> A cleanroom (facility) in normal operation with all services functioning and with production equipment and personnel present and performing their normal work functions in the facility.

3.5 <u>Unidirectional airflow.</u> (commonly known as laminar flow) Air flowing in a single pass in a single direction through a cleanroom or clean zone with generally parallel streamlines.

3.6 <u>Nonunidirectional airflow.</u> (commonly known as turbulent flow) Airflow which does not meet the definition of unidirectional airflow by having either multiple pass circulating characteristics or a nonparallel flow direction.

3.7 <u>Condensation nucleus counter.</u> An instrument for counting small airborne particles, approximately 0.01 micrometer and larger, by optically detecting droplets formed by condensation of a vapor upon the small particles.

3.8 <u>Optical particle counter.</u> A light-scattering instrument with display and/or recording means to count and size discrete particles in air.

3.9 <u>Particle.</u> A solid or liquid object generally between 0.001 and 1000 micrometers in size.

3.10 Particle size. The apparent maximum linear dimension of the particle in the plane of observation as observed with an optical microscope, or the equivalent diameter of a particle detected by automatic instrumentation. The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured.

3.11 Particle concentration. The number of individual particles per unit volume of air.

3.12 Student's t distribution. The distribution:

t = [(population mean) - (sample mean)]/[standard error]

obtained from sampling a Gaussian ("normal") distribution. (Available in tables in statistics texts.)

3.13 Upper confidence limit (UCL). An upper limit of the estimate of the mean, calculated in such a way that in a given percentage of cases (here, 95%) the upper limit of the estimate would be more than the true mean, if the means were sampled from a Gaussian ("normal") distribution.

4. Airborne particulate cleanliness classes.

4.1 Determination of class limits. Airborne particulate cleanliness classes listed in Table I shall be determined as follows:

TABLE I

Class limits in particles per cubic foot of size equal to or greater than particle sizes shown (micrometers)[a]

Class	Measured Particle Size (Micrometers)				
	0.1	0.2	0.3	0.5	5.0
1	35	7.5	3	1	NA.
10	350	75	30	10	NA.
100	NA.	750	300	100	NA.
1,000	NA.	NA.	NA.	1,000	7
10,000	NA.	NA.	NA.	10,000	70
100,000	NA.	NA.	NA.	100,000	700

(NA. - not applicable)

[a]The class limit particle concentrations shown in Table I and Figure 1 are defined for class purposes only and do not necessarily represent the size distribution to be found in any particular situation.

4.2 Particle sizes measured to determine Classes 100 and greater. Airborne particulate cleanliness classes shall be determined by measurement at any one of the particle sizes listed for the class in Table I. The class is considered met if the measured particle concentration is within the limits specified, at any one of the particle sizes shown in Table I, as determined by the statistical analysis of Paragraph 5.4.

4.3 Particle sizes measured to determine Classes less than 100. Airborne particulate cleanliness classes shall be determined by measurement at one or more of the particle sizes in Table I, as specified[1], and determined by the statistical analysis of Paragraph 5.4.

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[1]When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

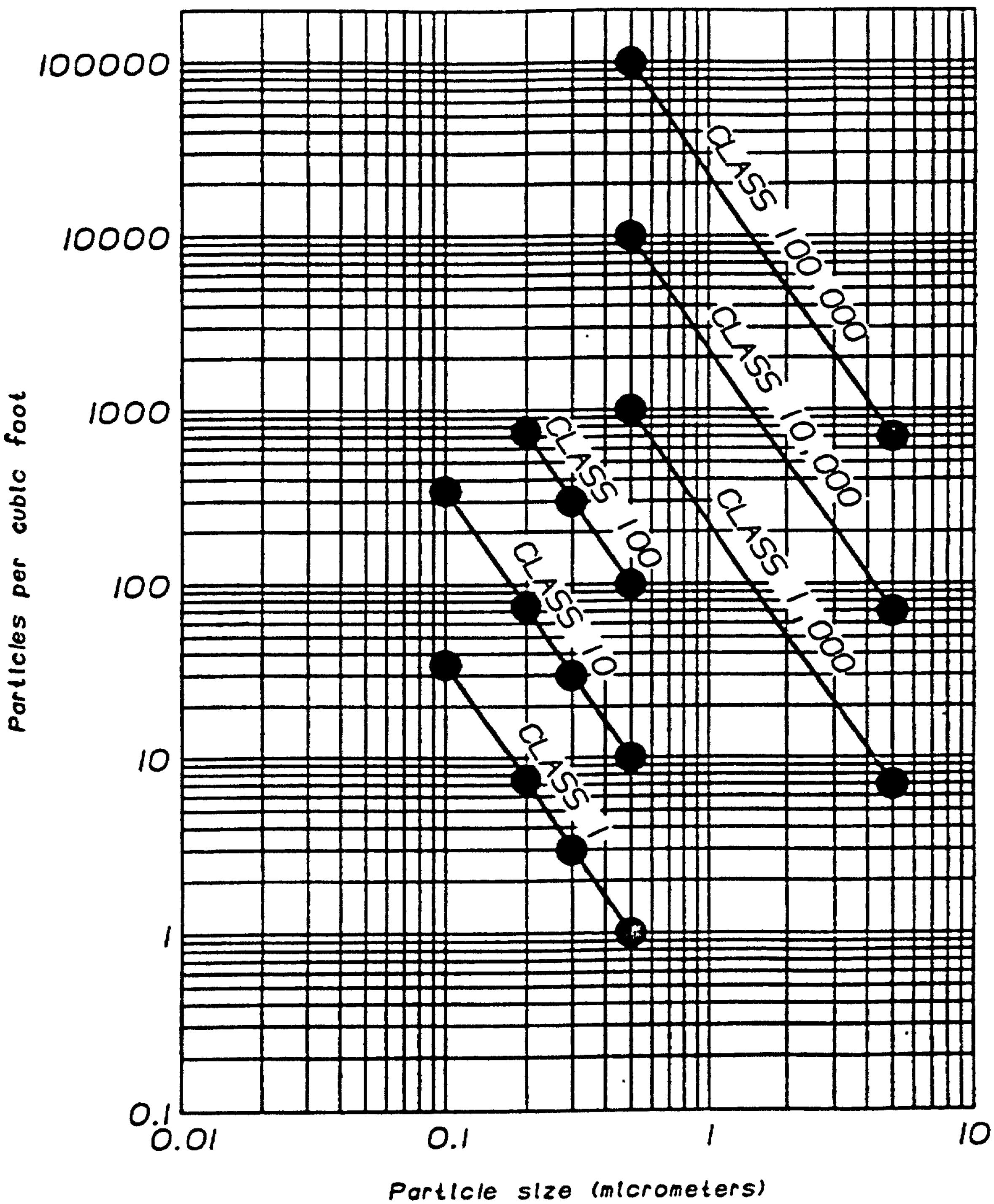

Figure 1. Class limits in particles per cubic foot of size equal to or greater than particle sizes shown*

*The class limit particle concentrations shown on Table I and Figure 1 are defined for class purposes only and do not necessarily represent the size distribution to be found in any particular situation.

4.4 Classification by measurement at other particle sizes. A classification of air cleanliness by measurement at particle sizes other than those specified herein may be performed with the following limitation: Particle counts may be interpolated between points but under no conditions may counts be extrapolated beyond the end points of Table I or Figure 1. The particle count limit for the next larger particle size in Table I must not be exceeded.

4.5 Provision for alternative airborne particulate cleanliness classes. Classes other than those stated in Table I (for example, 50, 300, 50,000, etc.) may be defined where special conditions dictate their use. Such classes will be defined by the intercept point on the 0.5-micrometer line in Figure 1, with a curve parallel to the established curves. Any curves that are used for these other classifications shall not be extrapolated to indicate concentrations for particles outside the following limits:

(a) Classes greater than 1,000 shall be determined by measurement at either 0.5 or 5 micrometers, as specified[1].

(b) Classes greater than 10 and less than 1,000 shall be determined by measurement at 0.2, 0.3, or 0.5 micrometer, as specified[1].

(c) Classes less than 10 shall be determined by measurement at one or more of the following particle sizes: 0.1, 0.2, 0.3, or 0.5 micrometer, as specified[1].

4.6 Particle counts for the determination of cleanliness classes. To determine an airborne particulate cleanliness class, particle counts shall be made in accordance with Section 5.

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[1]When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

5. Verification and monitoring of airborne particulate cleanliness classes.

5.1 Verification of airborne particulate cleanliness classes. The airborne particulate cleanliness class as defined in Section 4 shall be verified for a cleanroom or clean zone by measurement of airborne particle concentration under the following conditions.

5.1.1 Frequency. Verification tests shall be performed initially and at periodic intervals, or as specified[1].

5.1.2 Environmental test conditions. Verification of air cleanliness class shall be determined by particle concentration measurement under specified[1] operating conditions.

5.1.2.1 Conditions of test. The conditions of test of the cleanroom or clean zone shall be recorded as "as-built," "at-rest," "operational," or as otherwise specified[1].

5.1.2.2 Environmental and use parameters. The applicable environmental and use parameters of the cleanroom or clean zone shall be recorded. These conditions of measurement may include (but are not limited to) air velocity, air volume change rate, room air pressure, makeup air volume, unidirectional airflow parallelism, temperature, humidity, vibration, equipment, and personnel activity.

5.1.3 Particle counting. Particle counting shall be performed using a method specified in Paragraph 5.3 for verification of all classifications of cleanrooms and clean zones.

5.1.3.1 Sample locations and number - unidirectional airflow. For unidirectional airflow, the clean zone is identified by an entrance and an exit plane perpendicular to the airflow. The entrance plane shall be immediately upstream of the work activity

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[1] When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

area within the clean zone. The minimum number of sample locations required for classification of a clean zone shall be the lesser of (a) the area of the entrance plane (in square feet) divided by 25, or (b) the area of the entrance plane (in square feet) divided by the square root of the airborne particulate cleanliness class designation.

5.1.3.2 Sample locations and number - nonunidirectional airflow. For nonunidirectional airflow, the number of sample locations shall be uniformly spaced horizontally, and as specified[1] vertically, throughout the clean zone, except as limited by equipment within the clean zone. The minimum number of sample locations shall be equal to the square feet of floor area of the clean zone divided by the square root of the airborne particulate cleanliness class designation.

5.1.3.3 Sample location restrictions. No fewer than two locations shall be sampled for any clean zone. The number of sample locations shall be uniformly spaced throughout the clean zone except as limited by equipment within the clean zone. At least one sample shall be taken at each of the sampling locations specified in Paragraph 5.1.3.1 or 5.1.3.2. A total of at least five samples shall be taken. More than one sample may be taken at each location and different numbers of samples may be taken at different locations.

5.1.3.4 Sample volume and sampling time. Table II lists the minimum volume per sample for various airborne particulate cleanliness classes and measured particle sizes. The sample time is calculated by dividing the sample volume by the sample flow rate. A larger sample volume will improve the precision of the concentration measurements, decreasing the amount of variation between samples; however, the volume should not be so large as to render the sample time impractical. The particle concentration shall be reported in terms of particles per cubic foot of air regardless of the sample volume size. The sample volume size shall also be reported.

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[1]When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

TABLE II

Minimum volume per sample in cubic feet for the air cleanliness class and measured particle size shown

Class	Measured Particle Size (Micrometers)				
	0.1	0.2	0.3	0.5	5.0
1	0.6	3.0	7.0	20.0	NA.
10	0.1	0.3	0.7	2.0	NA.
100	NA.	0.1	0.1	0.2	NA.
1,000	NA.	NA.	NA.	0.1	3.0
10,000	NA.	NA.	NA.	0.1	0.3
100,000	NA.	NA.	NA.	0.1	0.3

(NA. - not applicable)

5.1.3.5 Sample volume at other classes or particle sizes. Sample volume for other classes or particle sizes not specified herein shall be the same as that specified for the next lower class or particle size.

5.1.4 Interpretation of the data. A statistical evaluation of particle concentration measurement data shall be performed according to Paragraph 5.4 to verify the airborne particulate cleanliness class level.

5.2 Monitoring of airborne particulate cleanliness. After verification, if specified[1], the airborne particulate cleanliness shall be monitored during operations. Monitoring shall consist of particle concentration measurements. Other environmental parameters as suggested in Paragraph 5.1.2.2 may also be monitored as specified[1] to indicate trends in airborne particulate cleanliness.

[1]When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

5.2.1 Monitoring plan. A monitoring plan shall be established based on the airborne particulate cleanliness class and the degree of cleanliness control necessary for work activity or product protection. The monitoring plan shall specify frequency, operating conditions, the method of counting particles, the locations, number, and volume of samples, and some method for interpretation of the sample data.

5.2.2 Particle counting. Particle counting shall be performed using one of the test methods in Paragraph 5.3, as specified[1]. Particle concentration measurements shall be taken at locations throughout the clean zone or where the cleanliness level is particularly critical or where the higher particle concentration levels are found during verification testing. The air shall be sampled as it reaches the clean zone.

5.3 Methods and equipment for measuring airborne particle concentration. The method and equipment to be used for measuring the airborne particle concentration shall be selected on the basis of the particle size of interest. The following methods are suitable for class verification and monitoring of air cleanliness unless otherwise specified[1]. Other particle counting methods and equipment may be used if demonstrated to have accuracy and repeatability equal to or better than the methods listed below[2,3].

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[1]When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

[2]For example, for particle size approximately 0.01 micrometer in diameter and larger, a condensation nucleus counter, which optically detects particles which have been grown by condensation of a supersaturated vapor, may be used. The counter must detect single particles.

[3]For monitoring purposes only, evaluation of particles by sedimentation methods may be carried out by allowing the particles to deposit on the surface of an appropriate medium and then counting them using optical microscopy.

5.3.1 Counting particles 5 micrometers and larger. For particle sizes 5 micrometers and larger, a manual sizing and counting method or an optical particle counting instrument shall be used. The manual sizing and counting method shall be in accordance with Appendix A, and the optical particle counting instrument shall be in accordance with Appendix B.

5.3.2 Counting particles 0.1 micrometer and larger. For particle sizes 0.1 micrometer and larger, an optical particle counting instrument shall be used in accordance with Appendix B. The instrument must count single particles. Only information obtained with a periodically calibrated and properly maintained particle counter shall be used in conducting airborne particle concentration measurements. Particle size data shall be reported in terms of equivalent diameter as calibrated against reference standard particles.

5.3.3 Limitations of particle counting methods.

5.3.3.1 Optical particle counters. Optical particle counters with unlike geometry or different operating principles may give different results when counting the same particles. Even recently calibrated instruments of like design may show differences in measurement results when sampling the same air. Caution should be used when comparing measurements from different instruments.

5.3.3.2 Microscopic evaluation. Since the microscopically measured size of a particle is the apparent longest linear dimension, and the size of particles measured by optical particle counters is based upon the diameter of a reference particle, microscopic counts will generally differ from counts obtained by optical particle counters.

5.3.3.3 Upper limits. Particle counters shall not be used to count particle concentrations or particle sizes greater than the upper limits specified by the manufacturer.

5.3.4 Calibration of particle counting instrumentation. All instruments shall be calibrated against known reference standards at regular intervals as specified[1]. Parameters which may need calibration include, but are not limited to, air flow rate and particle size.

5.4 Statistical analysis. The collection and analysis of airborne particle concentration data for verification of an airborne particulate cleanliness class shall be performed in accordance with the following requirements. This statistical analysis deals only with random errors (lack of precision), not errors of a nonrandom nature ("bias"), such as erroneous calibration.

5.4.1 Acceptance criteria. The cleanroom or clean zone shall meet the acceptance criteria for an airborne particulate cleanliness class if 1) the average of the particle concentrations (see Table I) measured at each location falls at or below the class limit, and 2) the mean of these averages falls at or below the class limit with a 95% confidence limit. The confidence limit shall be based on a one-tailed Student's t distribution, as follows.

5.4.1.1 Average particle concentration. The average particle concentration (A) at a location is the sum of the individual sample particle counts (C_i) divided by the number of samples taken at the location (N), as shown in Equation (5-1). If only one sample is taken, the average particle concentration is the same as the particle count measured.

$$A = (C_1 + C_2 + \ldots + C_N) / N \qquad (5\text{-}1)$$

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[1] When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet the requirements will be specified by the user or contracting agency.

5.4.1.2 Mean of the averages. The mean of the averages (M) is the sum of the individual averages (A_i) divided by the number of locations (L), as shown in Equation (5-2). All locations are weighted equally, regardless of the number of samples taken.

$$M = (A_1 + A_2 + \ldots + A_L) / L \qquad (5\text{-}2)$$

5.4.1.3 Standard deviation. The standard deviation (SD) of the averages is the square root of the sum of the squares of differences between each of the individual averages and the mean of the averages $(A_i-M)^2$ divided by the number of locations (L) minus one, as shown in Equation (5-3).

$$SD = \sqrt{\frac{(A_1 - M)^2 + (A_2 - M)^2 + \ldots + (A_L - M)^2}{L - 1}} \qquad (5\text{-}3)$$

5.4.1.4 Standard error. The standard error (SE) of the mean of the averages (M) is determined by dividing the standard deviation (SD) by the square root of the number of locations, as shown in Equation (5-4).

$$SE = SD / \sqrt{L} \qquad (5\text{-}4)$$

5.4.1.5 Upper confidence limit (UCL). The 95% UCL of the mean of averages (M) is determined by adding to the mean the appropriate UCL factor (see Table III for UCL factor) times the standard error (SE), as shown in Equation (5-5).

$$UCL = M + (UCL\ Factor \times SE) \qquad (5\text{-}5)$$

TABLE III

UCL factor for 95% upper control limit

No. of locations (L)	2	3	4	5-6	7-9	10-16	17-29	>29
95% UCL factor	6.3	2.9	2.4	2.1	1.9	1.8	1.7	1.65

5.4.1.6 Sample calculation. A sample calculation is shown in Appendix C.

6. Changes. When a Federal agency considers that this standard does not provide for its essential needs, written request for changing or adding to the standard, supported by adequate justification, shall be sent to the Administration. This justification shall explain wherein the standard does not provide for esssential needs. The request shall be sent to the General Services Administration, Federal Supply Service, Engineering Division, 819 Taylor Street, Fort Worth, TX 76102. The Administration will determine the appropriate action to be taken and will notify the agency.

7. Conflict with referenced specifications. Where the requirements stated in this standard conflict with any requirement in a referenced specification, the requirements of this standard shall apply. The nature of conflict between the standard and the referenced specification shall be submitted in duplicate to the General Services Administration, Federal Supply Service, Engineering Division, 819 Taylor Street, Fort Worth, TX 76102.

8. Federal agency interests.

Department of Commerce
Department of Defense, Office of the Assistant Secretary of Defense (Installations and Logistics)
- Army
- Navy
- Air Force

Department of Energy
Department of Health and Human Services
Department of Transportation
General Services Administration
National Aeronautics and Space Administration
Nuclear Regulatory Commission

APPENDIX A

PARTICLE MONITORING - MANUAL COUNTING AND SIZING METHODS

A10. Scope. This appendix describes procedures for determining airborne particulate contamination levels of particles 5 micrometers and greater in size in cleanrooms and clean zones by a membrane filtration and particle count method.

A20. Summary of method.

A20.1 Description of the basic method. At the sampling point, air is passed through a membrane filter using a vacuum to effect the filtration. The air flow rate is controlled by means of a limiting orifice or an air flowmeter, and the total volume of air sampled is controlled by the sampling time. The membrane filter is examined microscopically, using a high-intensity oblique incident light source, to determine the number of particles 5 micrometers and greater collected from the air sample.

A20.2 Alternatives to optical microscopy. Image analysis or projection microscopy can replace direct optical microscopy for sizing and counting, provided that the accuracy and reproducibility are equal to or better than those of the direct optical microscopic method.

A20.3 Acceptable sampling procedures. There are two acceptable procedures for this method as described herein: (a) Aerosol Monitor Method, and (b) Open Filter Holder Method. They differ primarily in the apparatus used and in the time required for performance.

A30. Equipment.

A30.1 Equipment common to both methods.

A30.1.1 Microscope. Binocular microscope with ocular-objective combinations for 100X to 250X magnifications. These combinations are chosen such that the ultimate smallest division of the ocular reticle, at the highest magnification, is less than or equal to 5 micrometers. The latter objective should have a numerical aperture of at least 0.25.

A30.1.2 Ocular micrometer scale: 5- or 10-millimeter linear scale with 100 divisions, dependent upon ocular-objective combinations, or micrometer eyepiece with movable scale.

A30.1.3 Stage micrometer: standard 0.01- to 0.1-millimeter-per-division scale.

A30.1.4 External microscope illuminator.

A30.1.5 Vacuum pump capable of maintaining a vacuum of 500 torr while pumping at a rate of at least 1 cubic foot per minute.

A30.1.6 Electrical timer or timing device, 60-minute range.

A30.1.7 Flowmeter or limiting orifice calibrated with the vacuum pump, filter holder, and filter to collect a sample of sufficient volume. See Paragraph A50.1.

A30.1.8 Manual tally counter.

A30.1.9 Filter storage holders for membrane filters after sampling; Petri plates or Petri slides with covers.

A30.1.10 Rinse fluid: purified water prefiltered to 0.45 to 1.2 micrometers.

A30.1.11 Forceps: flat, with unserrated tips.

A30.2 <u>Equipment for aerosol monitor method.</u>

A30.2.1 Aerosol monitors: dark, 0.8-micrometer mean pore size, with imprinted grid.

A30.2.2 Aerosol adapter.

A30.3 <u>Equipment for open filter holder method.</u>

A30.3.1 Filter holder: aerosol, open type.

A30.3.2 Membrane filter: dark, 0.8-micrometer or smaller pore size, with imprinted grid.

A30.3.3 Membrane filters: white (for evaluating dark particles), 0.8-micrometer or smaller pore size, with imprinted grid.

A30.4 <u>Optional equipment.</u>

A30.4.1 Image analyzer.

A30.4.2 Projection microscope and screen.

A40. Preparation of equipment.

A40.1 Preparation for both methods.

A40.1.1 All equipment preparation should be performed within a clean zone having an airborne particulate cleanliness class equal to or less than that of the clean zone to be monitored.

A40.1.2 All equipment should be maintained at maximum cleanliness and should be stored with protective covers, cases, or other suitable enclosures when not in use in a location having an airborne particulate cleanliness class equal to or less than that of the clean zone of lowest class number where sampling is performed.

A40.1.3 Personnel performing sampling, sizing, and counting operations should be equipped with garments consistent with the airborne particulate cleanliness class of the clean zone being monitored.

A40.1.4 Thoroughly rinse with purified water all internal surfaces of the Petri slide holders or Petri plates used to hold the exposed membranes for counting. Rinse in cascading action, as with the membrane holders. After rinsing, leave the lid open in a unidirectional airflow clean zone until the interior surfaces are dry.

A40.2 Preparation for aerosol monitor method.

A40.2.1 Establish a filter background count in the following manner. Where the manufacturer of aerosol monitors has indicated an average background count for a package of monitors (in the particle size ranges of concern), examine and establish the average background count for 5% of the filters in the package. If the average background count determined is equal to or less than the manufacturer's indication, use the indication as the background count for all filters in the package. If the determined count is higher than the manufacturer's indication, or if there is no such indication, establish a background count for each filter used.

A40.2.2 Background counts for individual filters are determined by following the microscopic procedures of Paragraph A70.

A40.2.3 After the background count has been established, package the aerosol monitors in a particle-free container or place into their appropriate sampling devices and transport them to the sampling location.

A40.2.4 Except for purposes of making background counts, aerosol monitors should be opened only when in the sampling location or the counting area.

A40.3 Preparation for open filter holder method.

A40.3.1 Disassemble the filter holder and wash in liquid soap and water. After washing, rinse and store in the unidirectional airflow clean zone until dry. (DO NOT WIPE DRY.) Deionized water or distilled water are the rinse media of choice.

A40.3.2 After the filter holder is completely dry, mount a membrane filter in the filter holder, with the grid exposed. After mounting the membrane filter, invert the filter holder assembly and thoroughly flush the filter surface area and exposed filter holder parts with purified water using a cascade rinsing action, starting at the top and progressing to the bottom of the filter face. Place in the unidirectional airflow clean zone and allow to dry.

A40.3.3 Establish a filter background count for each membrane filter to be used by following the procedures of Paragraph A70.

A40.3.4 After the interior surfaces of the filter storage holders are dry, apply a small piece of double-sided cellophane tape or stopcock grease to the bottom surface.

A40.3.5 After the filter holder and membrane are clean and dry, package them in a particle-free container.

A40.3.6 Transport the prepared filter holder, with membrane filter and vacuum source, to the sampling location. DO NOT EXPOSE THE FILTER SURFACE UNTIL THE APPARATUS IS ASSEMBLED AND READY FOR SAMPLING.

A50. Sampling.

A50.1 Sampling orientation and flow. For unidirectional airflow cleanrooms and clean zones, the aerosol monitor or filter holder should be oriented to face into the airflow. For non-unidirectional airflow cleanrooms and clean zones, orient the aerosol monitor or filter holder so that the opening faces upward, unless otherwise specified[1]. Airflow into the filter should be adjusted to be isokinetic for unidirectional airflow. For nonunidirectional airflow, the airflow into the filter should be adjusted to be 0.25 cubic foot per minute for a 25-millimeter filter or 1 cubic foot per minute for a 47-millimeter filter. The minimum sample volume should be 10 cubic feet for Class 1000 and 1 cubic foot for Class 10,000 and greater.

A50.2 Sampling by aerosol monitor method.

A50.2.1 At the sampling location, attach the aerosol monitor to the aerosol adapter and the adapter to the vacuum source. Have in line either a limiting orifice or a flowmeter. Isolate the vacuum pump exhaust from the area being sampled, as it may be a source of extraneous airborne contamination.

A50.2.2 Adjust the flowmeter, if used, for the flow rate at the operating vacuum pressure where it is used.

A50.2.3 Connect a timer to the vacuum pump power source.

A50.2.4 Remove the bottom plug from the aerosol monitor and attach it to the free end of the aerosol adapter. Position the aerosol monitor as required, pry off the top portion of the aerosol monitor, and store it in a clean location.

A50.2.5 Turn on the pump, adjust the flowmeter, and operate for a time which will provide the required sample at the chosen flow rate.

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[1]When the terms "as specified" or "shall be specified" are used without further reference, the degree of control needed to meet requirements will be specified by the user or contracting agency.

A50.2.6 When the sampling time has elapsed, release the vacuum, replace the top portion of the aerosol monitor, and remove the aerosol monitor from the aerosol adapter. The bottom plug need not be replaced. Identify the aerosol monitor with a sample identification tag. Transport the aerosol monitor to a counting area which should be a clean zone of airborne particulate cleanliness class at least equal to that of the clean zone sampled.

A50.3 Sampling by open filter holder method.

A50.3.1 When in the sampling area, place the filter holder in position. With the aid of vacuum tubing, connect the filter holder to the vacuum train which includes the filter holder, either a limiting orifice or a flowmeter, and a source of vacuum (vented outside the sampling area or filtered to prevent contamination of the area sampled).

A50.3.2 Adjust the flowmeter, if used, for the flow rate at the operating vacuum pressure where it is used.

A50.3.3 Remove the protective cover from the membrane filter holder and turn on the vacuum source. Turn on the pump, adjust the flowmeter, and operate for a time which provides the required sample at the chosen flow rate.

A50.3.4 At the end of the sampling period, turn off the vacuum source and carefully re-cover the filter holder with a precleaned cover. Return the covered sample filter holder to the counting area, which should be a clean zone of airborne particulate cleanliness class at least equal to that of the clean zone sampled.

A60. Microscope calibration.

A60.1 IF CALIBRATION OF THE MICROSCOPE HAS BEEN PERFORMED PREVIOUSLY BY THE OPERATOR, OMIT THIS SECTION.

A60.2 Place the stage micrometer on the mechanical stage; focus and adjust the light to give an even and full illumination in the field of view.

A60.3 Verify that the proper eyepiece and objective combination is in place to provide total magnification equal to 100X to 250X, as required.

A60.4 Assure that the microscope is properly focused by focusing each eyepiece to achieve a sharp stage micrometer image.

A60.5 If an image analyzer or projection microscope is used, perform a similar calibration.

A60.6 Using the entire length of the ocular reticle scale, record the number of stage micrometer divisions the eyepiece reticle covers.

(a) Compute the ocular micrometer scale calibration for a particular magnification by the formula:

Micrometers per ocular scale division =

$$\frac{\text{(No. of Stage Micrometer Div.)} \times \text{(Size of One Stage Micrometer Div.)}}{\text{(No. of Eyepiece Divisions)}}$$

Example:

At 100X: 100 eyepiece divisions equals 100 stage divisions, each 5.0 micrometers in length.

Thus: Micrometers/Eyepiece Division =

$$\frac{\text{(100 Divisions)} \times \text{(5.0 Micrometers)}}{\text{(100 Divisions)}} = \text{5.0 Micrometers}$$

(b) Calculate the number of linear divisions required to measure each range.

Example:

At 100X: each eyepiece division equals 5 micrometers, so for a 16- to 20-micrometer range, 3 to 4 divisions would be examined.

Note: If the microscope is equipped with a zoom adjustment, this may be employed to adjust the calibration to the nearest integer (X micrometers/division, instead of X.Y micrometers/division), provided the adjustment is noted in the calculations.

NOTE: A CHANGE IN INTERPUPILLARY DISTANCE BETWEEN OPERATORS CHANGES FOCAL DISTANCE, HENCE CALIBRATION.

A70. Microscopic counting and sizing of particles.

A70.1 In the clean zone where the particles upon the membrane filters are counted and sized, remove the membrane filter from the aerosol monitor or the open filter holder with unserrated flat forceps.

A70.2 Place the membrane filter, grid side up, in a precleaned Petri slide holder or Petri plate, allowing the filter to adhere to the sticky surface of the storage holder. Tightly seal the carrier to prevent contamination of the sample filter.

A70.3 The microscope should be clean so as not to add particulate contamination to the sample. Carefully place the covered Petri slide or Petri plate on the microscope stage and adjust the angle and focus of the illuminator to provide optimum particle definition at the magnification used for counting. Use an oblique lighting angle of 10 to 20 degrees to cast a shadow of the particle, thereby effectively separating the particle image from the filter background.

A70.4 Select a field size so that there are no more than about 50 particles larger than 5 micrometers in the field. Optional fields are: a grid square; a rectangle defined by the width of a grid square and the calibrated length of the ocular micrometer scale; a rectangle defined by the width of the grid square and a portion of the length of the ocular micrometer scale.

A70.5 Estimate the number of particles in the greater-than-5-micrometer range over the effective filtering area by scanning one unit area of the field size selected. If the total number of particles in this range is estimated to be less than 500, count the number of particles in this range over the entire effective filtering area. If the number is greater, the counting procedure in Paragraph A70.8.1 applies.

A70.6 In scanning for particles, manipulate the stage so that particles to be counted pass under the ocular scale. Only the maximum dimension of the particle is regarded as significant. The eyepiece containing the ocular micrometer may be rotated to accommodate specific particles, if necessary.

A70.7 Using a manual tally counter, record all particles in the selected field that are equal to or exceed the dimension as indicated by the ocular micrometer scale. Record the number of particles in each field counted, in order to establish uniformity of distribution and to have a record of the number of fields counted.

A70.8 Statistical particle counting.

A70.8.1 When the estimated number of particles over the effective filtering area exceeds 500, the method entails the selection of a unit area for statistical counting, counting all particles in the unit area, and then similarly counting additional unit areas until the following statistical requirement is met:

$$F \times N > 500$$

where:

F = number of grid squares or unit areas counted, and

N = total number of particles counted in F areas.

A70.8.2 Calculate the total number of particles on the filter as follows:

$$P = N \times \frac{A}{n \times a}$$

where:

P = total number of particles of a size range on the filter.

(When a background count is obtained, subtract this from the P value after calculation, but prior to dividing by sample volume.)

N = total number of particles counted in n unit areas.

n = number of unit areas counted.

a = unit area in square millimeters.

A = effective total filter area in square millimeters.

A80. Reporting.

A80.1 Subtract the background count for a filter from the total count obtained for the filter in accordance with Paragraph A70.

A80.2 Results should be expressed for each size range of specific interest, including 5-micrometer particles, in particles per cubic foot of sample by dividing the number of particles, P, by the sample volume (V).

$$\text{Particles per cubic foot} = P/V$$

A80.3 Final results are expressed in particles per cubic foot of sampled air, 5 micrometers and greater.

A90. Factors affecting precision and accuracy.

A90.1 The precision and accuracy of this method can be no higher than the sum total of the variables. In order to minimize the variables attributable to an operator, a trained microscopist technician is required. Variables of equipment are recognized by the experienced operator, thus further reducing possible error. The operator should have adequate basic training in microscopy and the techniques of particle sizing and counting.

A90.2 For training personnel, low- to medium-concentration specimens may be prepared on a grid filter and preserved between microslides as standards for a given laboratory. Standard counting specimens are available for this purpose.

A90.3 Accuracy for a sampling location can be increased by increasing the number of samples taken and processed at that sampling location.

A90.4 Accuracy for a sampling location can be increased by increasing the volume of air per sample and by increasing the time of sampling.

A90.5 Accuracy can be increased by establishing and using background counts for filters.

APPENDIX B

OPERATION OF OPTICAL PARTICLE COUNTERS

B10. Scope.

B10.1 Application. Optical particle counters provide data on airborne particle concentration and size distribution on a near-real-time basis. This appendix describes methods for the operation, use, and testing of optical particle counters used to satisfy requirements of this Federal Standard. Guidelines are given which should aid in standardization of optical airborne particle monitoring procedures for defining air cleanliness.

B10.2 Limitations. Particle size data are referenced to the particle system used to calibrate the optical particle counter; however, differences in optical, electronic, and sample handling systems among the various optical particle counters may contribute to variations in counting results. Care must be exercised in attempting to compare data from samples which vary significantly in particle composition or shape from the calibration base. Variations may also occur between instruments using particle sensing systems with different operating parameters. These effects should be recognized and minimized by using standardized methods for counter calibration and operation.

B10.3 Qualifications of personnel. Individuals performing the procedures described herein should be trained in the use of the optical particle counter and understand its operation, capabilities, and limitations.

B20. Applicable references.

B20. 1 ASTM F 328 Determining Counting and Sizing Accuracy of an Airborne Particle Counter Using Near-Monodisperse Spherical Particulate Materials.

B20.2 ASTM F 649 Secondary Calibration of Airborne Particle Counter Using Comparison Procedures, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

B20.3 IES-RP-CC-013 Recommended Practice for Equipment Calibration or Validation Procedures, Institute of Environmental Sciences, 940 East Northwest Highway, Mt. Prospect, IL 60056.

B30. Summary of method.

B30.1 Calibration. Primary calibration of optical particle counters is performed with spherical isotropic particles of refractive index 1.6. Secondary calibration may be performed with atmospheric particles for correlation with a reference particle counter. In addition, stable operation should be assured by standardizing against internal references built into the counter or by other approved methods.

B30.2 Operation. The air to be classified is sampled at a known flow rate from the sample point or points of concern. Particles contained in the sampled air pass through the sensing zone of the optical particle counter and produce a signal which is related to particle size. An electronic discriminator circuit sorts and counts the pulses in relation to particle size and displays or prints out the particle count in the sample volume.

B40. Apparatus and related documentation.

B40.1 Optical particle counting system. The optical particle counting system may include a recorder or printer; alternatively, data may be transmitted to a remote location for additional processing and computing.

B40.2 Sample air flow system. The sample air flow system consists of an intake tube, a sensing chamber, an air flow metering or control system, and an exhaust system. The exhaust system may consist of either a built-in vacuum source or an external vacuum supply with a separate flow control element for the optical particle counter in use. If a built-in vacuum source is used, and the optical particle counter is to be used where the exhaust air could affect either the particle counts being measured or operations in the cleanroom or clean zone, then the exhaust should be suitably filtered.

B40.3 Sensing system. The sensing system of the optical particle counter is formed by intersecting the sample air flow with a fixed sensing volume of such dimension so that the probability of more than one particle being present at any time (the coincidence error) is less than 5%. The signal produced from each particle passage through the sensing volume is received and processed by the electronic system in real time. The instrument should be designed to maintain its stated accuracy despite variations in the specified operating line voltage and ambient temperature. The operating line voltage and temperature ranges should be specified.

B40.4 Electronic system. The electronic system includes a pulse analyzer and counter, along with a system for registering particle counts in relation to particle size.

B40.4.1 The pulse analyzer may operate in either one or both of two modes: (1) in response to all particles within discrete size ranges, or (2) in response to all particles larger than the predetermined lower threshold size limit(s). Air cleanliness classification data, however, should be reported in terms of mode (2). Particle size ranges or limits may be either selectable or fixed.

B40.4.2 The counting circuits during a known time interval may accumulate information generated by the pulse analyzer in response to particle passages. Pulse count accumulation in one or more size ranges may be provided.

B40.4.3 For determination of the airborne particulate cleanliness class, the counting circuit is allowed to accumulate data for a preset time interval before reporting. The time interval is selected to yield a known sample volume, so that particle concentration can be readily calculated.

B40.4.4 The registering system indicates the number of particles or the particle concentration with respect to the selected particle size range(s) or size limit(s). Counts may be recorded or displayed on the optical particle counter, or may be transmitted to a remote location for recording, display, or computer processing.

B40.5 Calibration. An internal secondary calibration system or a means of ensuring stability should be provided in the instrument. The internal secondary calibration system should be capable of validation with respect to primary calibration in accordance with the methods of ASTM F 328 and ASTM F 649. The secondary calibration system is used for checking the sizing and counting stability of the optical particle counter and to provide a stable reference for any necessary sensitivity adjustment of the instrument.

B40.6 Documentation. Instructions which should be supplied with the instrument by the manufacturer include:

(a) Brief description of the operating principles of the instrument.

(b) Description of major components.

(c) Environmental conditions (ambient temperature, relative humidity, and pressure) and line voltage range required for stable operation.

(d) Particle size and concentration ranges for accurate measurement.

(e) Suggested maintenance procedure and recommended intervals for routine maintenance.

(f) Operating procedure for particle counting and sizing.

(g) Secondary calibration procedure (where applicable).

(h) Primary calibration procedure (a factory primary calibration facility should be available for calibration of the counter upon customer request), and field primary calibration capability and procedures.

(i) Suggested intervals for primary calibration.

B50. Preparations for sampling and counting. The procedures described in the following paragraphs should be performed or verified before the optical particle counter is used for determination of airborne particulate cleanliness classes. Each of the procedures has its own requirements regarding frequency interval.

B50.1 Primary calibration. Particle sizing and air sample volume require primary calibration. The comments in the following paragraphs are intended as a general guideline for primary calibration to be considered in interpreting ASTM F 328, ASTM F 649, or IES-RP-CC-013. Deviations may be necessary to achieve a specific objective. It is, however, the duty of the manufacturer to include in the operating instructions a description of the appropriate primary calibration method for the optical particle counter.

B50.1.1 Particle sizing. Primary calibration of the particle sizing function of the optical particle counter is carried out by registering the response of the counter to a monodisperse homogeneous and isotropic controlled aerosol containing predominantly spherical particles of known size and refractive index, and by adjusting the calibration control until the correct sizing response is obtained. Thereafter, the internal secondary calibration system is adjusted, if necessary, for correct response to the reference aerosol. Nonspherical particles may be used for primary calibration for specific applications. In these cases, the particle size is defined in terms of an appropriate dimension for the reference particles. Means of generating the reference particles has been extensively described in the literature[1].

B50.1.2 Air sample volume. The air sample volume is calibrated by measuring the flow rate and the duration of the sampling

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[1] For instance, Liu, B.Y.H., "Methods for Generating Monodisperse Aerosols." 1967. Publication #104, Particle Technology Laboratory, Department of Mechanical Engineering, University of Minnesota.

interval[2]. To avoid erroneous readings, equipment used for this measurement should not introduce an additional static pressure drop to the optical particle counter flow system. All flow measurements should be referenced to ambient conditions of temperature and pressure or as otherwise specified.

B50.2 Sampling setup.

B50.2.1 Sample location. In-place sample locations and orientation of the sample inlet tube should be established in accordance with Section 5 of this standard.

B50.2.2 Extension of sample inlet tube. Any extension of the sample inlet tube may affect the sampling results. The effects may be of little significance for particles in the size range from approximately 0.1 to 1 micrometer for sample tube extensions up to approximately 30 meters. Outside of this range, extensions of the sample inlet tube are used only if no other method is possible for sample acquisition. The sample tube extensions should be configured to maintain the sample flow Reynolds number in the range from 5,000 to 10,000 and the sample residence time in the extension below 5 seconds; no radius of curvature below 10 centimeters should be used. Where air sampling requires data on particles larger than 3 micrometers in diameter, no extension tube longer than 3 meters should be used.

B50.2.3 Particle counter exhaust air. The particle counter should be located and used so that air vented does not contaminate the sample or clean zone. The exhaust air should be filtered to a level consistent with the ambient airborne particulate cleanliness class or else vented outside of the cleanroom.

B50.3 Field calibration procedure. Perform secondary calibration or standardization (if applicable) in accordance with the manufacturer's instructions.

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[2] See Baker, W.C. and Pouchot, J.F., "The Measurement of Gas Flow Part I," 1983, Journal of Air Pollution Control Association, January, Vol. 33, No. 1 and Baker, W.C. and Pouchot, J.F., "The Measurement of Gas Flow Part II," 1983, Journal of Air Pollution Control Association, February, Vol. 33, No. 2.

B50.4 Zero count check. The absence of spurious counts is verified by a zero count check, as described in the following paragraphs.

B50.4.1 Place an appropriate filter on the counter sample inlet tube to prevent the passage of particles larger than the smallest size particle the counter can count.

B50.4.2 Turn on the sample air flow system; adjust for the specified sample air flow rate, if necessary.

B50.4.3 Turn on the counting circuits.

B50.4.4 Verify that the instrument reads zero counts for particles 0.5 micrometer and larger. If counts are registered, permit the counter to purge itself with the filter in place until a zero count level is reached.

B50.4.5 For counters capable of detecting particles smaller than 0.5 micrometer, zero counts may not be achievable for the smallest particles detectable. For such instruments, a tare concentration less than 10% of the airborne particulate cleanliness class concentration of such smaller particles (e.g., 0.1, 0.2, 0.3 micrometer) should be achieved.

B60. Counting procedure.

B60.1 Perform the field (secondary) calibration and zero count check, in accordance with Paragraphs B50.3 and B50.4.

B60.2 Check and adjust to the specified air flow rate (if applicable).

B60.3 Turn on the counting circuits, if necessary; read and record the particle count displayed for the particle size(s) of interest.

B70. Reporting.

B70.1 Record the particle size range(s), the volume of air sampled, the particle count, the time, and the sample point location.

B70.2 Report particle count data in terms of the number of particles per cubic foot of air sampled.

APPENDIX C

STATISTICAL ANALYSIS

C10. Sample calculation. The data and calculations presented in the following paragraphs are intended to serve as a working example, illustrating the statistical procedures involved in determination of acceptance criteria for cleanrooms and clean zones. The data and calculations are based upon a 1-cubic-foot sample volume and testing at 0.3-micrometer measured particle size for Class 10. (Note: Table 1 indicates that the UCL is to be less than or equal to 30 particles per cubic foot 0.3 micrometer and larger to meet Class 10.)

C10.1 Tabulation of particle count data.

Location	Particle Counts (C_i) 1	2	3	4	5	Total No. of Samples (N)	(ΣC_i) Total Count	(A_i) Average Counts
A	15	NR	NR	NR	NR	1	15	15.00
B	33	24	9	15	NR	4	81	20.25
C	18	3	12	24	NR	4	57	14.25
D	39	18	9	33	6	5	105	21.00
E	0	27	6	0	NR	4	33	8.25

(NR - no reading taken)

C10.2 Mean of averages (M).

$$M = (A_1 + A_2 + \dots + A_L) / L \qquad \text{(Equation 5-2)}$$

$$M = (15.00 + 20.25 + 14.25 + 21.00 + 8.25)/5 = 15.75$$

$$L = \text{(Number of sample locations)}$$

C10.3 Standard deviation of averages (SD).

(Equation 5-3)

$$SD = \sqrt{\frac{(A_1 - M)^2 + (A_2 - M)^2 + \ldots + (A_L - M)^2}{L - 1}}$$

$$SD = \sqrt{[(15.00-15.75)^2 + (20.25-15.75)^2 + (14.25-15.75)^2 + (21.00-15.75)^2 + (8.25-15.75)^2] / [5-1]}$$

SD = 5.17

C10.4 Standard error of mean of averages (SE).

$$SE = SD/\sqrt{L} \qquad \text{(Equation 5-4)}$$

$$SE = 5.17/\sqrt{5} = 2.31$$

C10.5 Upper 95% confidence limit (UCL).

For 5 locations, UCL factor = 2.1

UCL = M + (UCL Factor x SE) (Equation 5-5)

UCL = 15.75 + (2.1 x 2.31) = 20.6

C20. Conclusion. Since the upper 95% confidence limit (UCL) is less than 30 and all location average particle concentrations (A_i) were less than 30, the above data meet the acceptance criteria for Class 10, although some of the individual particle counts were above 30.

APPENDIX D

SOURCES OF SUPPLEMENTAL INFORMATION

D10. Scope. The purpose of this appendix is to list references for supplemental information which may provide instruction or guidance in the preparation of documents related to the design, acquisition, testing, operation, and maintenance of cleanrooms and clean zones. This listing of sources and documents emphasizes that information contained in such sources is not part of this standard and is not mandatory for compliance with this standard.

D20. Source references.

D20.1 AFWP - Headquarters, AFLC/DAPD, Wright-Patterson AFB, OH 45433

D20.2 AFWR - Warner Robins ALD/MMEDT, Robins AFB, GA 31098

D20.3 ANSI - American National Standards Institute, 1430 Broadway, New York, NY 10018

D20.4 ASHRAE - American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 1791 Tullie Circle Northeast, Atlanta, GA 30329

D20.5 ASME - American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

D20.6 ASTM - American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

D20.7 DOE - Nuclear Standards Management Center, Oak Ridge National Laboratory, Building 9204.1, Room 321, MS/10, P. O. Box Y, Oak Ridge, TN 37830

D20.8 IES - Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056

D20.9 MSFC - Marshall Space Flight Center, NASA, Marshall Space Flight Center, AL 35812

D20.10 NPFC - The Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

D20.11 NRC - U.S. Nuclear Regulatory Commission, Attn: Director, Division of Document Control, P-130A, Washington, DC 20555

D20.12 NSF - National Sanitation Foundation, 3465 Plymouth Road, P. O. Box 1468, Ann Arbor, MI 48106

D20.13 NTIS - National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161

D30. <u>Document references.</u>

D30.1

Document No.	AFM 88-4 Chapter 5	Source AFWP & AFWR
Title	Criteria for Air Force Clean Facility Design and Construction	
Abstract	Prescribes criteria for the design and construction of Air Force clean facilities. It specifies the real property standards for meeting the requirements of Air Force T.O. 00-25-203.	

D30.2

Document No.	T.O. 00-25-203	Source AFWP & AFWR
Title	Contamination Control of Aerospace Facilities, U.S. Air Force	
Abstract	This document specifies cleanroom design, operating, and test procedures. It also includes recommended cleanliness levels for typical operations.	

D30.3

Document No.	ASHRAE Std. 52-76	Source ASHRAE
Title	Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter	
Abstract	This standard defines unified test procedures and apparatus for evaluating filters with efficiencies below that of HEPA filters.	

D30.4

Document No.	F 25	Source ASTM
Title	Standard Method for Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications	

	Abstract	Procedures are given for membrane filter sampling and microscope counting in clean areas.
D30.5	Document No.	F 50 Source ASTM
	Title	Standard Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas Using Instruments Based upon Light Scattering Principles
	Abstract	Methods are given for sampling, particle counting, and data evaluation using light-scattering particle counters in cleanrooms.
D30.6	Document No.	F 91 Source ASTM
	Title	Standard Recommended Practice for Testing for Leaks in the Filters Associated with Laminar Flow Clean Rooms and Clean Work Stations by the Use of a Condensation Nuclei Detector
	Abstract	Provides a method of testing the integrity of HEPA filter installations in laminar flow cleanrooms and clean work stations.
D30.7	Document No.	F 328 Source ASTM
	Title	Standard Practice for Determining Counting and Sizing Accuracy of an Airborne Particle Counter Using Near-Monodisperse Spherical Particulate Materials
	Abstract	Counting and sizing accuracy determination procedures are given for certifying operation of an optical airborne particle counter.
D30.8	Document No.	F 649 Source ASTM
	Title	Standard Practice for Secondary Calibration of Airborne Particle Counter Using Comparison Procedures
	Abstract	Procedures are given for fine-tuning the response of an airborne particle counter to match that of a standard

		instrument for defining atmospheric dust, following calibration with monodisperse latex particles.
D30.9	Document No.	F 661 Source ASTM
	Title	Standard Practice for Particle Count and Size Distribution Measurements in Batch Samples for Filter Evaluation Using an Optical Particle Counter
	Abstract	Procedures are given for sample handling, sample evaluation, and particle count and size analysis in batch samples for use in an optical single particle counter. The method is directed at samples obtained in filter testing, but can be used for any samples.
D30.10	Document No.	IES-RP-CC-002 Source IES
	Title	Laminar Flow Clean Air Devices
	Abstract	Covers definitions, procedures for evaluating performance, and major requirements of laminar flow clean air devices. Sixteen test and performance criteria are considered.
D30.11	Document No.	IES-RP-CC-001 Source IES
	Title	HEPA Filters
	Abstract	Recommends basic provisions for HEPA filters for use in clean air devices and cleanrooms. Five levels of performance and two grades of construction are included.
D30.12	Document No.	IES-RP-CC-006 Source IES
	Title	Testing Clean Rooms
	Abstract	Describes test methods for characterizing the performance of cleanrooms. Performance tests are recommended for three types of cleanrooms at three operational phases.

D30.13	Document No.	IES-RP-CC-013 Source IES
	Title	Recommended Practice for Equipment Calibration or Validation Procedures
	Abstract	This Recommended Practice covers definitions and procedures for calibrating instruments used for testing cleanrooms and clean air devices, and for determining intervals of calibration.
D30.14	Document No.	NHB 5340.2 Source MSFC
	Title	NASA Standards for Clean Rooms and Work Stations for the Microbially Controlled Environment
	Abstract	Establishes standard classes of air conditions (both total particles and viable particles) within cleanrooms and clean work stations for the microbially controlled environment.
D30.15	Document No.	IES-CC-009 Source IES
	Title	Compendium of Standards, Practices, Methods and Similar Documents Relating to Contamination Control
	Abstract	Listing of documents.
D30.16	Document No.	MIL-STD-45622 Source NPFC
	Title	Calibration Systems Requirements
	Abstract	Prescribes requirements for establishment and maintenance of a calibration system used to control the accuracy of measuring and test equipment.
D30.17	Document No.	MIL-F-51068 Source NPFC
	Title	Military Specification: Filter, Particulate, High-Efficiency, Fire Resistant
	Abstract	Covers design, construction, and performance of HEPA filters in six sizes and seven types.
D30.18	Document No.	MIL-F-51079 Source NPFC
	Title	Military Specification: Filter Medium, Fire-Resistant, High-Efficiency

	Abstract	Provides requirements and test methods for determining compliance for one grade of HEPA filter medium.
D30.19	Document No.	MIL-F-51477 Source NPFC
	Title	Military Specification: Filters, Particulate, High-Efficiency, Fire Resistant, Biological Use
	Abstract	Covers general requirements for particulate filters for use in air cleaning or air filtration systems involving chemical, carcinogenic, radiogenic, or hazardous biological particles.
D30.20	Document No.	NE: F3-41 Source DOE
	Title	In-Place Testing of HEPA Filter Systems by the Single-Particle, Particle-Size Spectrometer Method
	Abstract	Procedures are described for in-place testing of single and tandem HEPA filter installations with DOP challenge and an optical particle counter with sensitivity to 0.1 micrometer.
D30.21	Document No.	NASA SP-5045 Source NTIS
	Title	Contamination Control Principles
	Abstract	Broad overview and guidelines to those designing or planning cleanroom facilities.
D30.22	Document No.	NASA SP-5074 Source NTIS
	Title	Clean Room Technology
	Abstract	Considerable information on history, need, nature, and type of cleanrooms with details of cleanroom environment and operation.
D30.23	Document No.	NASA SP-5076 Source NTIS
	Title	Contamination Control Handbook
	Abstract	Extensive detail on contaminants and their control and cleaning methods.

D30.24	Document No.	F 24 Source ASTM
	Title	Measuring and Counting Particulate Contamination on Surfaces
	Abstract	A method for size distribution analysis of particulate contamination, 5 micrometers and larger, either on, or washed from, surfaces of small electronic device components.
D30.25	Document No.	F 51 Source ASTM
	Title	Sizing and Counting Particulate Contaminant In and On Clean Room Garments
	Abstract	A membrane filter/microscope method for determining detachable particulate contaminants, 5 micrometers and larger, on cleanroom garments.
D30.26	Document No.	MIL-HDBK-406 Source NPFC
	Title	Contamination Control Technology - Cleaning Materials for Precision Precleaning and Use in Clean Rooms and Clean Work Stations
	Abstract	Extensive information on selection and use of cleaning materials developed by DOD.
D30.27	Document No.	MIL-HDBK-407 Source NPFC
	Title	Contamination Control Technology - Precision Cleaning Methods and Procedures
	Abstract	Extensive information on cleaning methods used by the military services for gross and precision cleaning of work processed under controlled environment conditions.

APPENDIX E

GLOSSARY

E10. Scope. This appendix lists terms used in the other appendixes, for which further explanation in the context of such use may benefit the user.

E20. List of terms.

E20.1 Isokinetic. A term describing a condition of sampling, in which the velocity of gas into the sampling device (at the opening or face of the inlet) has the same velocity rate and direction as the ambient atmosphere being sampled.

E20.2 Isotropic particles. Particles with equal, uniform physical and chemical properties along all axes.

E20.3 Membrane filter. Porous membrane composed of pure and biologically inert cellulose esters, polyethylene, or other materials through which the air stream is passed for the purposes of filtration.

E20.4 Reynolds number. A dimensionless number which is significant in the design of a model of any system in which the effect of viscosity is important in controlling the velocities or the flow pattern of a fluid: equal to the density of a fluid times its velocity, times a characteristic length, divided by the fluid viscosity.

PREPARING ACTIVITY:

GSA-FSS