



Designation: E2090-06 **Designation: E2090 – 12**

Standard Test Method for Size-Differentiated Counting of Particles and Fibers Released from Cleanroom Wipers Using Optical and Scanning Electron Microscopy¹

This standard is issued under the fixed designation E2090; 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 (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Techniques for determining the number of particles and fibers that can potentially be released from wiping materials consist of two steps. The first step is to separate the particles and fibers from the wiper and capture them in a suitable medium for counting, and the second step is to quantify the number and size of the released particles and fibers.

The procedure used in this test method to separate particles and fibers from the body of the wiper is designed to simulate conditions that the wiper would experience during typical use. Therefore, the wiper is immersed in a standard low-surface-tension cleaning liquid (such as a surfactant/water solution or isopropyl alcohol/water solution) and then subjected to mechanical agitation in that liquid. The application of moderate mechanical energy to a wiper immersed in a cleaning solution is effective in removing most of the particles that would be released from a wiper during typical cleanroom wiping. This test method assumes the wiper is not damaged by chemical or mechanical activity during the test.

Once the particles have been released from the wiper into the cleaning solution, they can be collected and counted. The collection of the particles is accomplished through filtration of the particle-laden test liquid onto a microporous membrane filter. The filter is then examined using both optical and scanning electron microscopy where particles are analyzed and counted. Microscopy was chosen over automated liquid particle counters for greater accuracy in counting as well as for morphological identification of the particles.

The comprehensive nature of this technique involves the use of a scanning electron microscope (SEM) to count particles distributed on a microporous membrane filter and a stereo-binocular optical microscope to count large fibers. Computer-based image analysis and counting is used for fields where the particle density is too great to be accurately determined by manual counting.

Instead of sampling aliquots, the entire amount of liquid containing the particles and fibers in suspension is filtered through a microporous membrane filter. The filtering technique is crucial to the procedure for counting particles. Because only a small portion of the filter will actually be counted, the filtration must produce a random and uniform distribution of particles on the filter. After filtration, the filter is mounted on an SEM stub and examined using the optical microscope for uniformity of distribution. Large fibers are also counted during this step. Once uniformity is determined and large fibers are counted, the sample stub is transferred to the SEM and examined for particles. A statistically valid procedure for counting is described in this test method. The accuracy and precision of the resultant count can likewise be measured.

This test method offers the advantage of a single sample preparation for the counting of both particles and fibers. It also adds the capability of computerized image analysis, which provides accurate recognition and sizing of particles and fibers. Using different magnifications, particles from 0.5 to 1000 μm or larger can be counted and classified by size. This procedure categorizes three classes of particles and fibers: small particles between 0.5 and 5 μm ; large particles greater than 5 μm but

¹ This test method 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. April 1, 2006: 2012. Published December 2006: May 2012. Originally approved in 2000. Last previous edition approved in 2000: 2006 as E2090 - 006. DOI: 10.1520/E2090-06.10.1520/E2090-12.

smaller than 100 μm ; and large particles and fibers equal to or greater than 100 μm . The technique as described in this test method uses optical microscopy to count large particles and fibers greater than 100 μm and SEM to count the other two classes of particles. However, optical microscopy can be employed as a substitute for SEM to count the large particles between 5 and 100 μm^2 .

1. Scope

1.1 This test method covers testing all wipers used in cleanrooms and other controlled environments for characteristics related to particulate cleanliness.

1.2 This test method includes the use of computer-based image analysis and counting hardware and software for the counting of densely particle-laden filters (see 7.7-7.9). While the use of this equipment is not absolutely necessary, it is strongly recommended to enhance the accuracy, speed, and consistency of counting.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*³

D1193 [Specification for Reagent Water](#)

F25 [Test Method for Sizing and Counting Airborne Particulate Contamination in Cleanrooms and Other Dust-Controlled Areas](#)

F312 [Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters](#)

2.2 *Other Documents:*

ISO 14644-1 [Cleanrooms and Associated Controlled Environments – Classification of Air Cleanliness](#)⁴

ISO 14644-2 [Cleanrooms and Associated Controlled Environments – Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1](#)⁴

Fed. Std. 209E [Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones](#)⁵

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *automatic counting, n*—counting and sizing performed using computerized image analysis software.

3.1.2 *cleanroom wiper, n*—a piece of absorbent knit, woven, nonwoven, or foam material used in a cleanroom for wiping, spill pickup, or applying a liquid to a surface.

3.1.2.1 *Discussion*—Characteristically, these wipers possess very small amounts of particulate and ionic contaminants and are primarily used in cleanrooms in the semiconductor, data storage, pharmaceutical, biotechnology, aerospace, and automotive industries.

3.1.3 *effective filter area, n*—the area of the membrane which entraps the particles to be counted.

3.1.4 *fiber, n*—a particle having a length to diameter ratio of 10 or greater.

3.1.5 *illuminance, n*—luminous flux incident per unit of area.

3.1.6 *particle, n*—a unit of matter with observable length, width, and thickness.

3.1.7 *particle size, n*—the size of a particle as defined by its longest dimension on any axis.

4. Summary of Test Method

4.1 *Summary of Counting Methods*—See the following:

| Counting Technique | Particle Size Range | | |
|------------------------------------|-----------------------|---------------------|---|
| | >100 μm | 5–100 μm | 0.5–5 μm |
| Stereobinocular optical microscope | 20 \times manual | ^A | NA ^B |
| Scanning electron microscope | NA | 200 \times auto | 3000 \times manual or automatic ^B |

^ASee Footnote 2.

^BNA = not applicable.

² The counting of particles 5 to 100 μm by optical microscopy is not described in this test method. However, procedures for counting particles in this size range are described in the Test Methods F25 and F312.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

⁴ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁵ Cancelled Nov. 29, 2001 and replaced with ISO 14644-1 and ISO 14644-2, FED-STD-209E may be used by mutual agreement between buyer and seller. Available from U.S. Government Printing Office, Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

5. Significance and Use

5.1 This test method provides for accurate and reproducible enumeration of particles and fibers released from a wiper immersed in a cleaning solution with moderate mechanical stress applied. When performed correctly, this counting test method is sensitive enough to quantify very low levels of total particle and fiber burden. The results are accurate and not influenced by artifact or particle size limitations. A further advantage to this technique is that it allows for morphological as well as X-ray analysis of individual particles.

6. Apparatus

- 6.1 *Scanning Electron Microscope*, with high-quality imaging and computerized stage/specimen mapping capability.
- 6.2 *Stereo-Binocular Optical Microscope*, with at least 40 \times -magnification capability equipped with a two-arm, adjustable-angle variable-intensity light source and a specimen holding plate.
- 6.3 *Orbital Shaker*, that provides 20-mm ($\frac{3}{4}$ -in.) diameter circular motion in a horizontal plane at 150 r/min.
- 6.4 *Microanalytical Stainless Steel Screen-Supported Membrane Filtration Apparatus*, with stainless steel funnel, TFE-fluorocarbon gasket and spring clamp.
- 6.5 *Vacuum Pump*, capable of providing a pressure of 6.5 kPa (65 mb) (49 torr) or lower.
- 6.6 *Cold Sputter/Etch Unit*, with gold or gold/palladium foils.
- 6.7 *Video Camera (3-CCD preferable)*, that can be attached to the stereo-binocular microscope and a monitor to provide video microscopy capability.
- 6.8 *Personal Computer (486-Type Processor or Better) and Monitor*.
- 6.9 *Frame-Grabbing Hardware and Image Analysis Software*, compatible with the personal computer.⁶
- 6.10 *Hand-Operated Tally Counter*.
- 6.11 *Stage Micrometer*, with 0.1- and 0.01-mm subdivisions.
- 6.12 *Horizontal, Unidirectional Flow Workstation*, with ISO Class 5 (Fed. Std. 209 Class 100) or cleaner air.

7. Materials

- 7.1 *Deionized Water*, in accordance with Specification D1193, Type III, 4.0×10^{-6} (Ω -cm)⁻¹ or better.
- 7.2 *Cleanroom Gloves* (for example, unpowdered latex gloves).
- 7.3 *Fine-Point, Duckbill Tweezers*.
- 7.4 *Forceps*, two pairs, with flat gripping surface tips.
- 7.5 *Glass Beakers*, 1.5 L, cleaned in accordance with 10.2.1.
- 7.6 *Polyethylene Photographic Tray*, approximately 250 by 340 by 45 mm cleaned in accordance with 10.2.1.
- 7.7 *Polycarbonate Membrane Filters* (typically 0.1- to 0.4- μ m pore size), white, and 25-mm diameter.
- 7.8 *Petri Slide*, 47 mm.
- 7.9 *SEM Aluminum Specimen Stubs*, typically 32-mm diameter by 10-mm height.
- 7.10 *Polystyrene Latex Microspheres* (sizes 0.5 and 5 μ m) for use in calibration (see Section 9).⁷
- 7.11 *Carbon Paint*, for SEM stub preparation.
- 7.12 *Low-Surface-Tension Cleaning Liquid*—Any 8- to 10-mole ethoxylated-octyl- or nonyl-phenol-type surfactant⁷ prepared as a 0.1 % stock solution in deionized water. This solution will facilitate the release of both nonpolar and polar contaminants and can serve as a general test standard across industries. However, this test method is not limited to a specific cleaning solution and only requires that the cleaning liquid used be relatively free of particles and fibers. It is recommended that the cleaning liquid most relevant to the product end use be considered for this test method.

8. Preparation of Apparatus

- 8.1 *Setting Up Stereo-Binocular Optical Microscope*—See Section 10.
- 8.2 *Fiber Counting by Optical Microscopy*—See Section 10.
- 8.3 *Setting Up Scanning Electron Microscope (SEM)*—See Section 10.
- 8.4 *Particle Counting by SEM*—See Section 10.

9. Calibration and Standardization

9.1 For the fiber counting by optical microscopy, the size calibration at 20 \times magnification can be done by comparing the fiber sizes, as visualized in the video monitor, with the rulings on the stage micrometer (with 0.1- and 0.01-mm subdivisions). For the

⁶ “Image-Pro Plus,” Version 3.0.7, available from Media Cybernetics, has been found to be satisfactory for this test method.

The sole source of supply of the apparatus known to the committee at this time is Media Cybernetics. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

⁷ Triton® X-100 manufactured by Rohm and Haas Co. has been found to be satisfactory for this test method.

The sole source of supply of the apparatus known to the committee at this time is Rohm and Haas Co. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

equipment described above, a linear dimension of 8 mm in the video screen equaled 100 μm . The conversion factors are equipment-dependent and users of this test method shall establish the relation between screen size and object size.

9.2 In the SEM study, to determine the values of the start and the end areas for the computer-assisted automatic particle counting, it is necessary to perform the size calibration study by experimenting with standard-sized particles such as polystyrene microspheres or actual particles of known dimensions which can be ascertained by using the micrometre bar measurement tool available on most SEMs.

9.3 To prepare a stub with 0.5- and 5- μm spheres, add 10 μL of each of the 0.5- and 5- μm sphere suspensions to a beaker containing 500 mL of deionized water.

9.4 Filter the solution using a new membrane filter.

9.5 Prepare the SEM stub. Save the stub in a clean container as a standard size reference for the automatic particle counting at 200 and at 3000 \times .

9.6 For the manual procedure at 3000 \times , avoid counting particles having approximate linear lengths of 25 μm and up, as those will have sizes larger than 5 μm as determined from measurements done against the micrometre bars at various magnifications in the SEM.

10. Procedure

10.1 The procedure consists of two parts: preparing the sample and counting the fibers and particles. Fibers and particles greater than 100 μm are counted using an optical microscope at 20 \times magnification; large (between 5 and 100 μm) and small (between 0.5 and 5 μm) particles are counted using an SEM at 200 and 3000 \times magnifications respectively. Both manual and computer-aided automatic counting methods are used in this procedure.

10.1.1 *Sample Preparation*—Sample preparation consists of two steps:

10.1.1.1 Preparation of a background filter stub and

10.1.1.2 Preparation of the sample filter stub containing particles released from a cleanroom wiper.

10.2 *Preparation of a Background Filter Stub*—To measure the background level of particles from the glassware, polyethylene tray, and filtration system, it is necessary to prepare an experimental blank.

10.2.1 The cleaning of the photographic tray, glassware, and the filtration apparatus should be accomplished in the following manner:

10.2.1.1 Clean the photographic tray thoroughly by rinsing the inner surface at least five times with deionized water.

10.2.1.2 Ultrasonically clean the glassware, storage containers, and filtration assembly then thoroughly rinse using deionized water.

10.2.1.3 Allow all containers and assemblies to drain dry in the unidirectional flow workstation.

10.2.1.4 Store all containers and assemblies, including the photographic tray, in the clean workstation to prevent environmental contamination.

10.2.2 The choice of the cleaning solution should reflect the liquid that the wiper will come in contact with during actual use. A typical example of a cleaning solution would be a low-concentration surfactant/deionized water mixture (see 7.12). This mixture serves well as a standard for general comparative purposes since it facilitates the release of both nonpolar and polar contaminants. However, this test method is not limited to a specific cleaning solution and only requires that the solution be relatively free of particles and fibers. The specific cleaning solution used must be reported in accordance with 12.1.2. A low-concentration surfactant/deionized water mixture as described in 7.12 is used in the test method example.

10.2.3 *Stock 0.1 % Surfactant Solution Preparation:*

10.2.3.1 Place 300 mL of deionized water in a 1.5-L beaker.

10.2.3.2 Place the beaker on a hot plate and raise the water temperature to 40°C.

10.2.3.3 Slowly add 1 g (35 drops) of the concentrated surfactant into the hot water.

10.2.3.4 Mix well to make the solution homogeneous.

10.2.3.5 Add more deionized water to raise the volume to 1 L.

10.2.3.6 Aliquots from this stock solution will be used for the test procedure.

10.2.3.7 The stock solution shall be prepared daily to prevent any biological growth.

10.2.4 *Blank Preparation:*

10.2.4.1 Place 500 mL of deionized water into the clean photographic tray.

10.2.4.2 Place the tray on the platform of an orbital shaker (Fig. 1) stationed inside the hood of a clean workstation having of an ISO Class 5 (Fed. Std. 209 Class 100) or cleaner environment.

10.2.4.3 Add a 25-mL aliquot from the stock 0.1 % surfactant cleaning solution to the water in the tray.

10.2.4.4 Run the orbital shaker at 150 r/min for 5 min. Some equipment may require somewhat lower rotation rates, for example, 130 r/min, to avoid liquid spills.

10.2.5 Insert the base of the filtration assembly into the stopper. Place the TFE-fluorocarbon gasket onto the base, then place

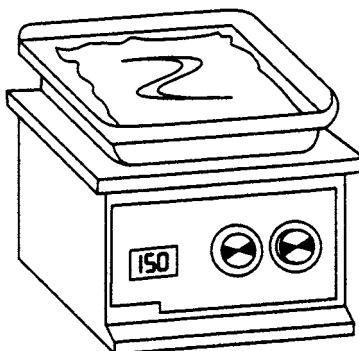


FIG. 1 Orbital Shaker

the stainless steel screen on top of the gasket.⁸ Insert the stopper holding the base, gasket and screen into the filtration flask.

10.2.6 Connect the filtration flask to the vacuum pump but do not turn the pump on at this point.

10.2.7 Transfer a 25-mm diameter polycarbonate membrane filter to a petri slide with the filter shiny (coated) side facing up using a fine-point duckbill tweezer.

10.2.8 Rinse the filter gently under running deionized water.

10.2.9 Using the tweezers, slide the filter from the petri slide onto the stainless steel screen of the filtration apparatus with the shiny (coated) side of the filter facing up.

10.2.10 Place the stainless steel funnel on top of the filter and clamp the assembly together. Fig. 2 shows the fully assembled vacuum filtration apparatus.

10.2.11 Pour the water from the tray into a clean 1.5-L beaker.

10.2.12 Add approximately 25 mL of clean deionized water to rinse the tray and pour this water into the beaker as well.

10.2.13 Slowly pour the water from the beaker into the filtration funnel until the funnel is approximately two thirds full.

10.2.14 Turn on the vacuum pump and adjust the vacuum so that the filtration rate is approximately 50 mL/min.

10.2.15 Continue to transfer the water from the beaker to the funnel until the entire contents of the baker are emptied into the filter funnel.

10.2.16 Add approximately 25 mL of clean deionized water to rinse the beaker and pour this water into the filter funnel as well. Ensure that the filter funnel remains filled with solution from the beaker until the filtration is complete.

10.2.17 Remove the funnel and carefully transfer the filter onto a clean SEM specimen stub, using fine-point duckbill tweezers.

10.2.18 Allow the filter to air dry in an ISO Class 5 (Fed. Std. 209 Class 100) or cleaner environment.

10.2.19 Affix the perimeter of the filter to the specimen stub by applying several (at least four) spots of conductive carbon paint.

10.2.20 Transfer the stub to the vacuum sputtering unit and apply a gold coating to the filter. Typically, 20 s – 40 s sputter time will provide adequate gold coverage, depending on the equipment used.⁹

10.2.21 Label the sample as the background count for this particular experiment and place it in a clean, covered container. Set it aside for subsequent particle enumeration. The counting procedures are described in 10.4 and 10.5. If there is concern that the background may exhibit excessive contamination, then the operator may wish to reverse the order of counting described in 10.5.14, that is, count the background first and delay preparation of the sample stub (10.3) until there is confidence that there are no contamination issues in the set up.

⁸ For example, see the assembly diagram in <http://www.millipore.com/catalogue.nsf/docs/C804>. Permission to reference this copyrighted image is provided as a courtesy by the Millipore Corporation.

⁹ The application of a vacuum in the sputtering unit will not remove or disturb particles on the surface of the filter. Recovery studies are documented in Footnote 15.

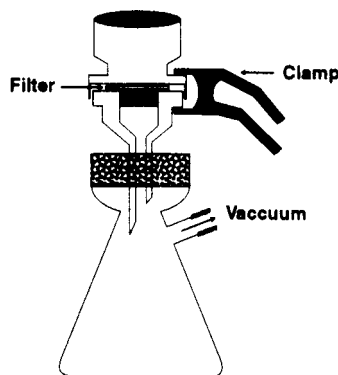


FIG. 2 Filtration Assembly

10.2.22 After preparing the blank, the wiper sample is prepared using the same glassware and filtration system.

10.2.23 Accurate counts in the test wiper sample require subtracting background counts from the sample counts. The value of the background count should be less than 15 % of the sample count. If this is not the case, reclean the apparatus and perform the experiment again. For very clean wipers which may exhibit very low counts in the >100 μm range, this requirement may be lifted.

10.3 *Preparation of Sample Stub:*

10.3.1 Place 500 mL of deionized water into the same photographic tray that was used in preparation of the background sample.

10.3.2 Place the tray on the platform of the orbital shaker (Fig. 1).

10.3.3 Add a 25-mL aliquot from the stock surfactant cleaning solution (see 10.2.2 and 10.2.3) to the water in the tray.

10.3.4 Shake the tray for 1 min to facilitate the mixing of surfactant and water.

10.3.5 Using cleanroom gloves, open the bag of wipers to be tested.

10.3.6 Using two pairs of clean forceps, carefully lift a wiper from the bag and gently drape the wiper onto the surface of the water in the tray.

10.3.7 Run the shaker at 150 r/min for 5 min.

10.3.8 Using the forceps, lift the wiper from the tray slowly by holding two adjacent corners, allowing the excess water to drip into the tray.

10.3.9 Measure the dimensions of the wiper to two significant figures and set the wiper aside.

10.3.10 Pour the water from the tray into the beaker previously used for the background sample preparation.

10.3.11 Add approximately 25 mL of clean deionized water to rinse the tray and pour this water into the beaker as well.

10.3.12 Complete the sample preparation for the test specimen by repeating 10.2.7-10.2.21, using a new membrane filter from the same package. Some wipers may have excessive numbers of particles that can overload the filter, making it impossible to obtain accurate counts. In these cases, one samples a representative portion of the water of the beaker and filters only that portion. As an example, if 25 mL of the total 550 mL were sampled for filtration, this would represent only 25/550th of the available particles. The actual particle count on the wiper would be calculated by multiplying the particles counted in the representative portion by 550/25, then subtracting the blank value.

10.3.13 Label the sample as the test specimen for the particular experiment.

10.4 Manual counting of >100- μm fibers and particles.

10.4.1 Place the wiper sample stub in the specimen-holding mount plate and then place the mount plate on the *x-y* stage of the optical microscope (see Fig. 3).

10.4.2 Set the microscope at the lowest magnification and its circular iris dial in the middle of its range.

10.4.3 Turn on the illuminator and adjust the knobs to have adequate and uniform illumination on the stub.

10.4.3.1 To obtain the uniformity, set one of the arms of the light guide so the light grazes the surface of the membrane filter (approximately 15 to 30° angle between the light beam and the surface of the filter).

10.4.3.2 Set the other arm from the other side of the filter, again with the light grazing the filter surface.

10.4.3.3 The illuminance can be varied by adjusting the iris dial and by slightly adjusting the knobs of the illuminator back and forth.

10.4.4 Bring the particles/fibers on the filter surface to focus by adjusting the focus knob while observing the field through the microscope eyepieces.

10.5 *Viewing Fields From the Optical Microscope:*

10.5.1 To make the counting process more convenient, the images from the sample stub can be viewed in the video monitor using a video camera and a computer with frame-grabbing hardware and software. Connect the R, G, B leads from the computer to the corresponding R, G, B leads from the video camera, allowing the image to be displayed on the video monitor.

10.5.2 Focus the microscope so that the particles and fibers on the filter are seen brightly and clearly in the monitor. Readjust the arms of the light guide to make the distribution of light on the filter as uniform as possible, as viewed in the monitor. Direct the light to the filter stub at a grazing angle of approximately 15 to 30° between the light beam and the surface of the filter.

10.5.3 Change the magnification to 40 \times and readjust the light so that the field is completely illuminated and refocus the microscope. The purpose of focusing at high magnification is to ensure accurate viewing at the lower magnifications.

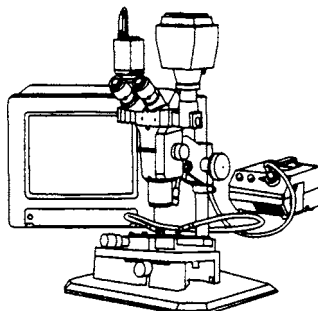


FIG. 3 Optical Microscope