

Institute of Environmental Sciences and Technology

IENT-RP-CC001.7

Contamination Control Division
Recommended Practice 001.7

HEPA and ULPA Filters



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RP-CC001.7 WHAT IS NEW AND IMPROVED

What is new:

- An Appendix with a draft of an alternate filter classification scheme relating classes to filter efficiency consistently instead of the nonsequential letter Types. This being a new proposed scheme, it is included in an appendix for user comments and suggestion and may be considered as a recommended filter class in a future revision.
- An Appendix providing guidelines for system qualification for testing filter sizes with high aspect ratio, i.e., narrow and long. This is based on work done at NASA to test the filters used on the International Space Station.
- Appendix describing operation and results of a low output ‘thermal’ aerosol generator for testing filters. Based on feedback from users, this may be included as a recommended generator in future revisions of the RP.

What is improved:

- Text on the testing of filters made with ePTFE or charged media.
- Table D2 edited for improved clarity.
- Cautionary notes on the use of solid aerosol challenge and charge on it.
- Correction of a legacy error in HEPA acronym to High Efficiency Particle Arrestance.

HEPA and ULPA Filters

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1 SCOPE AND LIMITATIONS

This Recommended Practice (RP) covers basic provisions for HEPA (high-efficiency particulate air) and ULPA (ultra-low penetration air) filter units as a basis for agreement between customers and suppliers.

Filters that meet the requirements of this RP are suitable for use in clean air devices and cleanrooms that fall within the scope of ISO 14644 and for use in supply air and contaminated exhaust systems that require extremely high filter efficiency (99.97% or higher) for submicrometer (μm) particles.

This RP describes 11 levels of filter performance, or types, and six grades of filter construction. For the types and grades that require scanning, these filter types generally apply to rectangular filters. Semi-circular, cylindrical, V-bank filters, and other construction configurations may not be readily scanned and thus will not meet the requirements of the filter types requiring scanning. While many of the performance measurement techniques can be adapted to other filter configurations, the filter types as described in this RP should be applied only to rectangular, flat panel filters. The customer's purchase order should specify the level of performance and grade of construction required. The customer should also specify the filter efficiency required if the efficiency level is not covered by the performance levels specified in this RP.

NOTE: Products and procedures discussed in this RP may involve hazardous materials, operations, and equipment. This RP does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use of this RP.

2 REFERENCES

The following documents are incorporated into this RP to the extent specified herein. If no specific edition is cited, the most recent edition should be used. Where specific editions are cited, subsequent revisions of these publications do not automatically supersede the cited editions and users should investigate the applicability of revised editions.

2.1 Reference Documents

ANSI A208.1: Particleboard, Mat-Formed Wood

APA PS 1: Structural Plywood

ASME AG-1: Code on Nuclear Air and Gas Treatment

ASTM A176: Standard Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip

ASTM A240: Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

ASTM A653: Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

ASTM A1008: Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

ASTM B209: Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

ASTM B766: Standard Specification for Electrodeposited Coatings of Cadmium

ASTM C209: Standard Test Methods for Cellulosic Fiber Insulating Board

ASTM D1056: Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber

ASTM E84: Standard Specification for Surface Burning Characteristics of Building Materials

IEST-RP-CC002: Unidirectional-Flow, Clean-Air Devices

IEST-RP-CC006: Testing Cleanrooms

IEST-RP-CC007: Testing ULPA Filters

IEST-RP-CC013: Calibration Procedures and Guidelines for Select Equipment Used in Testing Cleanrooms and Other Controlled Environments

IEST-RP-CC021: Testing HEPA and ULPA Filter Media

IEST-RP-CC031: Method for Characterizing Outgassed Organic Compounds from Cleanroom Materials and Components

IEST-RP-CC034: HEPA and ULPA Filter Leak Tests

ISO 14644: Cleanrooms and Associated Controlled Environments

MIL-STD-282: Filter Units, Protective Clothing, Gas-Mask Components, and Related Products: Performance Test Methods

NSF/ANSI 49: Biosafety Cabinetry: Design, Construction, Performance, and Field Certification

QQ-S-698: Steel Sheet and Strip, Low Carbon

SAE-AMS-QQ-P-416: Plating, Cadmium, Electro-Deposited

UL 586: Standard for High Efficiency, Particulate, Air Filter Units

UL 900: Standard for Test Performance of Air Filter Units

2.2 Sources and Addresses

AA

Aluminum Association
1525 Wilson Blvd., Suite 600
Arlington, VA 22209, USA
Phone: 703-358-2960
Fax: 703-358-2961
www.aluminum.org

ANSI

American National Standards Institute
25 West 43rd Street
New York, NY 10036, USA
Phone: 212-642-4900
Fax: 212-398-0023
www.ansi.org

APA

APA-Engineered Wood Association
7011 South 19th Street
Tacoma, WA 98466, USA
Phone: 253-565-6600
Fax: 253-565-7265
www.apawood.org

ASME

ASME International
3 Park Avenue
New York, NY 10016-5990, USA
Phone: 800-843-2763
Fax: 212-591-7674
www.asme.org

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428, USA
Phone: 610-832-9500
Fax: 610-832-9555
www.astm.org

FM

Factory Mutual Research Corporation
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P.O. Box 7500
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Phone: 401-275-3000
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www.fmglobal.com

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ISO (National Standards)

In US, ISO 14644 documents:
IENT
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Schaumburg, IL 60173, USA
Phone: 847-981-0100
Fax: 847-981-4130
www.iest.org

MIL/QQ (Military Standard)

Standardization Document Order Desk
700 Robbins Avenue
Bldg. #4, Section D
Philadelphia, PA 19111-5094, USA
<http://quicksearch.dla.mil/>

NSF

NSF International
P.O. Box 130140
789 N. Dixboro Road
Ann Arbor, MI 48113-0140, USA
Phone: 734-769-8010
Fax: 734-769-0109
www.nsf.org

UL

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062, USA
Phone: 847-272-8800
Fax: 847-272-8129
www.ul.com

3 TERMS AND DEFINITIONS

aerosol

A gaseous suspension of fine solid or liquid particles.

aerosol generator

A device that can supply an aerosol from an oil or microsphere source, in a concentration range and with a mean size suitable for the measurements described in this RP.

aerosol photometer (or photometer)

An instrument that measures mass concentrations of aerosol using the forward light scattering principle for multiple particle scattering. For the applications described in this RP, the instrument should be capable of measuring aerosol concentrations of up to 100 µg/L and have a threshold sensitivity capable of measuring 0.0001 µg/L. The device should have a detection limit of at least $0.1 \times$ the designated leak. The device should have a volumetric flow rate of 28.3 L/min (1.0 ft³/m).

calibrated equipment

Test equipment that has been calibrated in accordance with the manufacturer's recommendations or accepted industry practices.

challenge aerosol

An aerosol derived from the selected aerosol source material and used as the challenge for a filter leak and/or global penetration test. Challenge aerosols may be produced by a variety of methods, with the choice determined by the aerosol type and the particle size characteristics.

cleanroom

A room in which the air supply, air distribution, filtration of air supply, materials of construction, pressure gradients, and operating procedures are regulated to control airborne particle concentrations to meet established air cleanliness levels, as defined by ISO 14644-1.

count or number mean diameter of aerosol

The average particle size of the number distribution of the aerosol.

count or number median diameter of aerosol (CMD)

The 50th percentile of the number distribution of the aerosol; i.e., 50% of the particles are smaller than the count median diameter and 50% are larger than the count median diameter.

designated leak

Any penetration that has exceeded the maximum allowable penetration.

diluter

A device that reduces the particle concentration of the challenge aerosol by the dilution ratio of the device. These devices typically mix a known volume of sample air with a known volume of particle-free or filtered air to achieve the dilution. The ratio of the two volumes is the dilution ratio.

discrete-particle counter (DPC)

An instrument, such as an optical particle counter or condensation nucleus counter, capable of resolving and counting responses from individual particles. The device should be capable of measuring and sizing the challenge aerosols over

the particle size range of interest. The threshold size of the DPC should be equal to or smaller than the particle size(s) being measured.

DOP or DEHP

Diethyl phthalate (DOP) or di(2-ethylhexyl) phthalate (DEHP); CAS# 117-81-7.

DOS or DEHS

Diethyl sebacate (DOS) or di(2-ethylhexyl) sebacate (DEHS); CAS# 122-62-3.

field bench test

A leak test performed on HEPA or ULPA filters after unpacking at the location of use and prior to installation in the clean-air device or cleanroom. A portable test system is used.

HEPA filter

High Efficiency Particle Arrestance (also commonly called High Efficiency Particle Air) filter.

An extended-medium, dry-type filter in a rigid frame when tested at rated airflow having a minimum particle collection efficiency of 99.97% for 0.3- μ m mass median diameter particles of DOP when tested in accordance with MIL-STD-282.

Laskin nozzle

A nozzle used as part of a system to generate a heterogeneous aerosol from a liquid, such as PAO, DOP, or other oil, that uses a source of compressed gas as shown in IEST-RP-CC013.

Laskin-nozzle-generated aerosol

An aerosol generated by a Laskin nozzle from PAO, DOP, or other oil.

mass mean diameter of aerosol

The particle diameter size that is the average particle size of the mass distribution of the aerosol. Typically, because the mass of a particle varies as the cube of its diameter, most of the mass of an aerosol tends to be in the larger sizes, resulting in the mass mean being larger than its count or number mean.

mass median diameter of aerosol (MMD)

The 50th percentile of the mass distribution of the aerosol; i.e., 50% of the mass of the aerosol is made up of particles smaller than the mass median diameter and 50% of the mass of the aerosol is made up of particles larger than the mass median diameter.

microspheres (or PSL)

Monodisperse or polydisperse sized particles usually made of polystyrene latex (PSL). Monodisperse particle size is traceable to the National Institute of Standards and Technology (NIST) or other national standards bodies with respect to the diameter.

NOTE: PSL refers to a common type of highly uniform spheres, or a suspension thereof, used to generate a solid aerosol. PSL is useful for leak testing filters where other aerosols may contaminate the filters in an unacceptable manner. The term *latex* refers to an emulsion in water of finely divided particles of synthetic rubber, plastic, or other elastomer, and is not to be confused with natural rubber latex.

most-penetrating particle size (MPPS)

The particle size at which a given filter has its highest penetration (or lowest efficiency); i.e., the worst-case particle size with respect to filtration efficiency. From filtration theory, the efficiency is higher for particle sizes smaller or

larger than the MPPS. In practice, the MPPS of a filter is considered to be within a measured size range typical in commercial instruments rather than at one unique particle size.

PAO (4 cSt polyalphaolefin)

A grade of PAO with a viscosity of 4 centistokes at 100 °C. With reference to filter testing, PAO also refers to a polydisperse aerosol of the described material.

penetrometer

A self-contained instrument for the determination of penetration characteristics of very high-efficiency filter medium and filter units with thermally generated DOP, in accordance with MIL-STD-282.

photometer (see aerosol photometer)

PSL (see microspheres)

scanning

A method for disclosing leaks in HEPA and ULPA filters where the inlet of the sampling probe of an aerosol photometer or discrete-particle counter is moved in a series of parallel, slightly overlapping strokes across the test area at a distance of approximately 2.5 cm (1 in.) from the filter face and at a rate based on the leak penetration to be detected and the upstream concentration of the challenge aerosol.

single particle counter (see discrete-particle counter)

standard local penetration

The penetration that would be measured by a photometer or particle counter with a 28.3-L/min (1-ft³/min) sample flow rate when the sample probe is stationary over the leak.

super ULPA (ultra-low-penetration air) filter

An extended-medium, dry-type filter in a rigid frame, made with a filter medium having a minimum particle collection efficiency of > 99.9999% (i.e., a maximum particle penetration of < 0.00010%) for particles of the most-penetrating particle size (MPPS) when tested at the average medium velocity in the filter in accordance with the methods of IEST-RP-CC021.

thermal generator

A device that produces a liquid aerosol by means of an evaporation-condensation process in the absence of controlled nucleation. The particle size distribution and mass median diameter (MMD) of an aerosol produced by a thermal generator are measurably different from those of an aerosol from a Laskin nozzle.

thermally generated aerosol

An aerosol generated by quenching (condensing) vapor that has been evaporated from oils such as DOP or PAO by heat.

thermal aerosol, MIL-STD-282

A DOP aerosol generated by vapor condensation that meets the MIL-STD-282 requirement, which specifies that the light polarized by the aerosol is $29 \pm 1^\circ$ as measured by a Tyndall (optical) Owl. This aerosol has a mass mean of 0.3 µm. (Penetrometers built to meet this standard have reported count mean sizes closer to 0.2 µm with a narrow distribution.)

Tyndall Owl

An optical device to measure the angle of polarization of white light scattered by the aerosol, usually by means of a pair of polarizing glass plates rotated relative to each other when viewing light.

ULPA filter

Ultra-Low-Penetration Air filter.

A throwaway, extended-medium, dry-type filter in a rigid frame, having a minimum particle-collection efficiency of 99.9995% (that is, a maximum particle penetration of 0.0005%) when tested in accordance with the methods of IEST-RP-CC007.

4 PERFORMANCE

4.1 General

4.1.1 Penetration

Penetration should be measured in accordance with section 9 of this RP and should correspond with the classifications listed in section 4.2 for the type of filter specified.

Nanoparticle penetration: Nanoparticles are generally considered to be those particles that have diameters smaller than 100 nm. The mechanisms for particle capture by HEPA and ULPA filters described in this RP lead to the commonly known penetration curve with its distinct most-penetrating particle size (MPPS). Current research by Pui et al. shows that this type of penetration curve is valid for particles as small as 20 nm. That is, testing and classifying filters at or near the MPPS per this RP will yield the worst-case classification even when nanoparticles are involved.

4.1.2 Resistance to airflow

The resistance of the filter should be measured at the rated volumetric airflow, for all sizes of most filters. Filters constructed to meet ASME AG-1 requirements are tested to 33 mm (1.3 in.) w.g. The resistance should be determined from pressure measurements upstream and downstream of the filter, using appropriate measurement practices and equipment as agreed upon between the customer and the supplier. It is recommended that measurements be made in a direction normal (perpendicular) to the flow direction to minimize the effects of velocity pressure. When it is not possible to test filters at the standard temperature of 70 °F (21.1 °C), it is recommended that the resistance be corrected for the temperature effect on the viscosity, as shown in IEST-RP-CC007. Other resistance parameters may be specified by agreement between the customer and the supplier.

4.1.3 Airflow uniformity

Some or all types of filters referred to in this document may be used in applications requiring uniform airflow velocities at the rated airflows. When measured across the face of the filter, the velocity of the airflow should be uniform within limits agreed to between the customer and the supplier. Typically, the airflow uniformity is the average velocity $\pm 20\%$. Appropriate methods of measurement may be found in IEST-RP-CC002, NSF/ANSI 49, or as agreed upon between the customer and the supplier.

4.1.4 Outgassing

Filters referred to in this document may be used in applications requiring low outgassing of molecular contaminants. The amount and type of outgassing allowable is to be determined by agreement between the customer and the supplier. RPs for measuring outgassing may be found in IEST-RP-CC031 or as agreed upon between customer and supplier.

4.1.5 Other classification

To improve the clarity of filter classes and filter efficiency, an alternate nomenclature is suggested in Appendix E. It is cautioned that this suggested nomenclature is presented only for information and for soliciting feedback in

comparison to the traditional letter performance levels listed in section 4.2. This suggested scheme is also in closer alignment with the ISO standard classification.

4.2 Performance Levels

Specification of performance based on leak criteria should be more stringent for testing the filter as manufactured than for testing by field bench test or after installation.

4.2.1 Cautionary considerations in test aerosol

Filter Types A–D are tested using a 0.3 μm MMD aerosol generated by the method specified in MIL-STD-282, in which the aerosol size is verified by a Tyndall Owl. The MIL-STD-282–specified aerosol results in a nominal 0.3 μm MMD particle size. This same aerosol measured by contemporary means (i.e., Scanning Mobility Particle Sizer) equates to a 0.18–0.20 μm count median diameter (CMD). Users should be aware that the efficiency of this filter may be much higher at 0.3 μm CMD compared to its efficiency when tested per MIL-STD-282, and the results should not be used for classifying the filter.

It has also been established that substituting the MIL-STD aerosol with one prescribed by NIOSH 42 CFR Part 84, using DOP or equivalent (i.e., PAO), will garner comparable results. This cold, neat, nebulized PAO aerosol is defined as 0.18 $\mu\text{m} \pm 0.02$ CMD with geometric standard deviation of less than 1.6. Other alternate methods for generating the test aerosol are not recommended.

Type C filters are often used for isolators, workstations, and biosafety cabinets that require periodic *in situ* (field) filter leak testing with Laskin nozzle–generated aerosols. However, if *in situ* testing will be conducted using thermally generated aerosol with a smaller aerosol size, for safety it is recommended that these filter types be specified at 99.995%. When specifying these filters tested with aerosol photometers, a special note clarifying this requirement is recommended. Alternatively, a Type K filter may be specified as agreed to between user and supplier.

4.2.2 Type A filter

A filter that has been tested at rated flow in accordance with section 9.1.1. The minimum filter efficiency of the encapsulated filter for this type of filter is 99.97% when tested with MIL-STD-282 thermal aerosol or equivalent.

4.2.3 Type B filter

A filter that has been tested for overall penetration at rated flow and at 20% of rated flow, in accordance with section 9.1.1. The minimum filter efficiency of the encapsulated filter in this type is 99.97% when tested with MIL-STD-282 thermal aerosol or equivalent. It is possible for a HEPA filter to have a leak and still pass the overall penetration at its rated flow. A filter with a leak will have a higher penetration at 20% of rated flow than at 100% rated flow. A filter without a leak will have an equal or lower penetration at the lower flow rate.

4.2.4 Type C filter

A filter that has been tested for overall penetration in accordance with section 9.1.1 and, in addition, has been leak tested in accordance with IEST-RP-CC034. The minimum filter efficiency of the encapsulated filter in this type is 99.99% when tested with MIL-STD-282 thermal aerosol or equivalent. The designated leak for this filter is 0.010%.

4.2.5 Type D filter

A filter that has been tested for overall penetration in accordance with section 9.1.1 and, in addition, has been leak tested in accordance with IEST-RP-CC034. The minimum filter efficiency in this type is 99.999% when tested with MIL-STD-282 thermal aerosol or equivalent. The designated leak for this filter is 0.0050%.

4.2.6 Type E filter—No longer in use

Intentionally left blank. This filter type is obsolete.

4.2.7 Type F filter

A filter that has been efficiency tested at rated flow in accordance with the methods of IEST-RP-CC007 and, in addition, has been leak tested in accordance with IEST-RP-CC034. The minimum efficiency for this filter type is 99.9995% and is determined as the lower efficiency when tested for particle size ranges of 0.1–0.2 μm and 0.2–0.3 μm . The designated leak for this filter is 0.00250%.

4.2.8 Super ULPA—Type G filter

A filter that has been tested in accordance with IEST-RP-CC007 for overall penetration and has been tested for leaks in accordance with IEST-RP-CC034. The minimum efficiency for the Type G filter is 99.9999% at its MPPS, where the MPPS is determined according to IEST-RP-CC021. The designated leak for this filter is 0.00010%.

NOTE: Due to the very low penetration and hence very low counts downstream of these filters, in practice, only the medium for this filter is tested for efficiency and the filter is tested only for leaks.

4.2.9 Type H filter

A filter that has been efficiency tested at rated flow in accordance with the methods of IEST-RP-CC007. The minimum efficiency for this filter type is 99.97% and is determined as the lower efficiency when tested for particle size ranges of 0.1–0.2 μm and 0.2–0.3 μm .

4.2.10 Type I filter

A filter that has been efficiency tested at rated flow and 20% of rated flow in accordance with the methods of IEST-RP-CC007. The minimum efficiency for this filter type is 99.97% and is determined as the lower efficiency when tested for particle size ranges of 0.1–0.2 μm and 0.2–0.3 μm .

4.2.11 Type J filter

A filter that has been efficiency tested at rated flow in accordance with the methods of IEST-RP-CC007 and, in addition, has been leak tested in accordance with IEST-RP-CC034. The minimum efficiency for this filter type is 99.99% and is determined as the lower efficiency when tested for particle size ranges of 0.1–0.2 μm and 0.2–0.3 μm . The designated leak for this filter is 0.010%.

4.2.12 Type K filter

A filter that has been efficiency tested at rated flow in accordance with the methods of IEST-RP-CC007 and, in addition, has been leak tested in accordance with IEST-RP-CC034. The minimum efficiency for this filter type is 99.995% and is determined as the lower efficiency when tested for particle size ranges of 0.1–0.2 μm and 0.2–0.3 μm . The designated leak for this filter is 0.0080%.

5 CONSTRUCTION GRADES

Several construction grades are defined here to distinguish among the types of service the filter units may experience. Certain specifications and applications correspond to each of the construction grades listed in sections 5.1 to 5.6. Types of tests and their purposes are detailed in each section. These tests are to be performed on a design qualification and follow-up basis only.

5.1 Grade 1—No Longer in Use

Intentionally left blank. This grade is not in use.

5.2 Grade 2 (UL 586)

This type of filter uses fire-retardant construction throughout and meets additional moisture and low-temperature exposure tests. Except for the low-temperature test, all of these tests are equivalents of those listed in ASME AG-1