Institute of Environmental Sciences and Technology

IEST-RP-CC021.4

Contamination Control Division
Recommended Practice 021.4

Testing HEPA and ULPA Filter Media

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1 SCOPE AND LIMITATIONS

1.1 Scope

This Recommended Practice (RP) discusses test methods for physical and filtration properties of high-efficiency particulate air (HEPA) and ultra-low penetration air (ULPA) filtration media.

Application of this RP is by mutual agreement between the customer and the supplier. Use of this RP should be applied, but not be limited to:

a) Acceptance criteria for test methods;

b) Test aerosol and particle size;

c) Test face velocity.

1.2 Limitations

This RP does not include discussion of special applications testing, such as nuclear, biological, chemical, and other such testing. Although the general approach to testing media outlined in this RP may be used for testing media with lower efficiencies than HEPA media, the user is cautioned that specific recommendations noted on aerosols, statistics, instrumentation, and other factors may not be appropriate.

NOTE: Testing in accordance with 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 establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

2 REFERENCES

The following documents are incorporated into this RP to the extent specified herein. Users should apply the most recent editions of the references.

2.1 Reference documents

ASTM F778-88 2007: Standard Methods for Gas Flow Resistance Testing of Filtration Media

IEST-RP-CC001: HEPA and ULPA Filters

IEST-RP-CC007: Testing ULPA Filters

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

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IEST-RP-CC014: Calibration and Characterization of Optical Airborne Particle Counters

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

NIOSH 42 CFR Part 84 Respiratory Protective Devices.

NIOSH Manual of Analytical Methods Procedure 500.

TAPPI-T211: Ash in Wood, Pulp, Paper and Paperboard

TAPPI-T410: Grammage of Paper and Paperboard

TAPPI-T411: Thickness (Caliper) of Paper, Paperboard, and Combined Board

TAPPI-T413: Ash in Wood, Pulp, Paper, and Paperboard: Combustion at 900 Degrees C

TAPPI-T494: Tensile Breaking Properties of Paper and Paperboard (Using Constant Rate of Elongation Apparatus)

TAPPI-T543: Bending Resistance of Paper (Gurley- Type Tester)

2.2 Sources and Addresses

ASTM
American Society for Testing and Materials
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National Institute for Occupational Safety and Health
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3 TERMS AND DEFINITIONS

aerosol
A gaseous suspension of fine solid or liquid particles.

aerosol source material
Aerosols used for testing HEPA or ULPA filter media produced from a specified liquid having known properties. One commonly used aerosol source material is dioctyl phthalate (DOP), also known as di(2-ethylhexyl) phthalate (DEHP).

airflow rate
The airflow rate expressed as volumetric flow per unit of time.

air resistance
The loss of pressure caused by gas moving through the filter medium.

basis weight
The mass of a specified area of filter medium; also referred to as grammage.

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

correlation ratio

The ratio of downstream counts to upstream counts with no filter in the test system (see Appendix B1).

For sequential counting systems, the correlation ratio represents the differences in the upstream and downstream sampling systems, such as:

- particle losses in sample lines and test duct
- diluter (if used)
- sample times

For simultaneous counting systems, the correlation ratio represents the same factors as for sequential counting systems, as well as the differences between the different particle counting instruments used upstream and downstream, such as:

- sample flow rate
- counting efficiency

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.

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

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

filter medium
A permeable material that separates solid particles or liquid droplets from a fluid passing through it.

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grammage
See basis weight.

HEPA (high-efficiency particulate air) filter
An extended-medium, dry-type filter in a rigid frame having a minimum particle collection efficiency of 99.97% for 0.3-µm mass median diameter particles of DOP when tested at the rated airflow in accordance with MIL-STD-282.

NOTE: The foregoing is the traditional definition for the HEPA filter. Changes in filter manufacture, end user requirements, and testing have introduced products that vary parametrically from filters that have been considered standard according to this definition. Additional information on this topic is given in IEST-RP-CC001.

laminar flow
Streamline flow in a fluid (such as air) near a solid boundary (such as a duct wall), characterized by an upper-limit Reynolds number.

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 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.

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.

particle concentration
The number of particles detected per unit volume of air.

particle size
The apparent maximum linear dimension of a 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. Current particle size range of interest can vary upward from sizes smaller than 0.1 µm.

PAO (4 cSt poly-alpha-olefin)
A grade of PAO with a viscosity of 4 centistokes at 100 °C. With reference to filter testing, PAO also refers to a poly disperse aerosol of the described material.

penetration
The ratio of the number of particles exiting the filter to the number of particles entering the filter, per unit time, expressed as a percentage for a stated particle size range (see Appendix B, sections B5 and B6). It can also be the ratio of mass of the aerosol challenge measured with photometry.

> **observed penetration**
> The penetration calculated from observed counts.
>
> **true mean penetration**
> The penetration that would be calculated from the average observed counts, if the tests were repeated indefinitely.
>
> **UCL and LCL penetration**
> The 95% upper confidence limit (UCL) penetration and 95% lower confidence limit (LCL) penetration are values statistically calculated from the observed counts. There is a 95% confidence that the true mean penetration is between the UCL and LCL penetrations.

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percent elongation
The percent increase in the dimension of the material in the direction of stress at the point of failure.

sequential counting system
A system that uses a single detector to determine the concentrations of the test aerosol, both upstream and downstream of the filter medium, by alternating the sampling locations of the detector.

simultaneous counting system
A system that uses a pair of detectors to determine simultaneously the concentrations of the test aerosol upstream and downstream of the filter medium.

stiffness
Resistance to bending when flexural stress is applied.

tensile strength
The maximum stress a material can withstand when subjected to stretching.

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

thickness
The dimension perpendicular to the plane of the filter medium.

ULPA (ultra-low-penetration air) filter
A throwaway, extended-medium, dry-type filter in a rigid frame, having a minimum particle-collection efficiency of 99.999% (that is, a maximum particle penetration of 0.0010%) when tested in accordance with the methods of IEST-RP-CC007. ULPA filters are defined and described in IEST-RP-CC001.

water repellency
The ability of a filter medium to resist wetting.

4 TEST METHODS

4.1 Test for resistance to airflow

Resistance to airflow should be tested according to ASTM-F778, observing the exceptions noted in section 4.1.3 of this RP.

4.1.1 Resistance to airflow test description

This test method describes a procedure for measuring airflow resistance (pressure drop) across a sample of known geometry at one or more airflow rates. It is recommended that airflow for testing air resistance of HEPA and ULPA media be laminar.

4.1.2 Resistance to airflow test equipment

a) Medium holding device, or chuck (Figure 1, item 4)

The medium holding device should be a cylinder of simple construction, preferably a pneumatically actuated top clamp with low-surface-area sealing.

All materials used in the medium test system that contact the test airstream, including sampling lines, should be cleanable, corrosion-resistant, electrically conductive and grounded, and should shed minimal particles. The preferred materials are polished stainless steel and anodized aluminum.

The velocity profile across the face of the medium should be ±10%. There should be no recirculation zones or uncirculated areas that trap particles in the chuck flow path.

The recommended test area is 100 cm^2 (15.5 in^2).

If a support grid is used, the effect of the support grid on the measured sample pressure drop should be less than 1%.

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The medium holding device should be leak-free. Any gaskets used for securing the sample should not damage the sample. This may require extra care when testing delicate materials such as ePTFE or nano fiber filter media.

b) Pressure drop taps

Pressure drop should be measured with a differential pressure device that is connected to pressure taps on both upstream and downstream sides of the test medium. Pressure taps should be of the static-pressure rather than the total-pressure type, and mounted at right angles to the airflow to minimize velocity effects on the measurements.

It is recommended that the taps be located a distance of at least one diameter of the test medium away from the medium to minimize turbulence effects resulting from changes in the cross section of the test duct.

c) Manometer or suitable pressure transducer

Typical tolerance is ±2% of full scale (span).

d) Tare

Tare, which is the test fixture resistance without the test media in place, should be measured at the sample flow rate and subtracted from the media test results.

4.1.3 Resistance to airflow test procedure

The test should be conducted according to ASTM-F778, with the following exceptions:

- The area of the test sample should be known to within ±2%.
- The face velocity should be 5.33 cm/sec (10.5 ft/min) unless otherwise agreed upon by the customer and the supplier.

4.1.4 Data reporting for resistance to airflow test

Pressure drop measurement should be reported in millimeters of water column.

4.1.5 Equipment qualification and calibration for resistance to airflow test

Calibration should be performed according to ASTM-F778. See Appendix A for calibration frequency.

4.2 HEPA and ULPA filter media penetration test

Penetration of HEPA and ULPA filter media can be determined with the use of various test instrumentations. Both photometric and particle count (see Appendix B4) techniques and particles smaller than 0.1 µm are capable of providing valid penetration measurement data for HEPA and ULPA filter media.

To present comparable data, it is recommended that both the penetration test data and the test technique be stated, in addition to the correlated value of the penetration as determined by photometric method. More information is available in ASTM-D2986 and MIL-STD-282 (see Appendix D).

4.3 HEPA filter media penetration test—photometric method

The following procedure presents the equipment, terms, aerosol, processes, and calculations used in determining the efficiency of HEPA filter media using photometry. The discussion provides guidelines for constructing a suitable test and sampling system using thermally generated aerosol as described.

Figure 1 shows the basic components of a typical test system. System design should also recognize that large volumes, low velocities, recirculating regions, or stalled regions in the flow path lead to long system response times. Refer to ASTM D2986 and MIL-STD-282 for additional insight and details.

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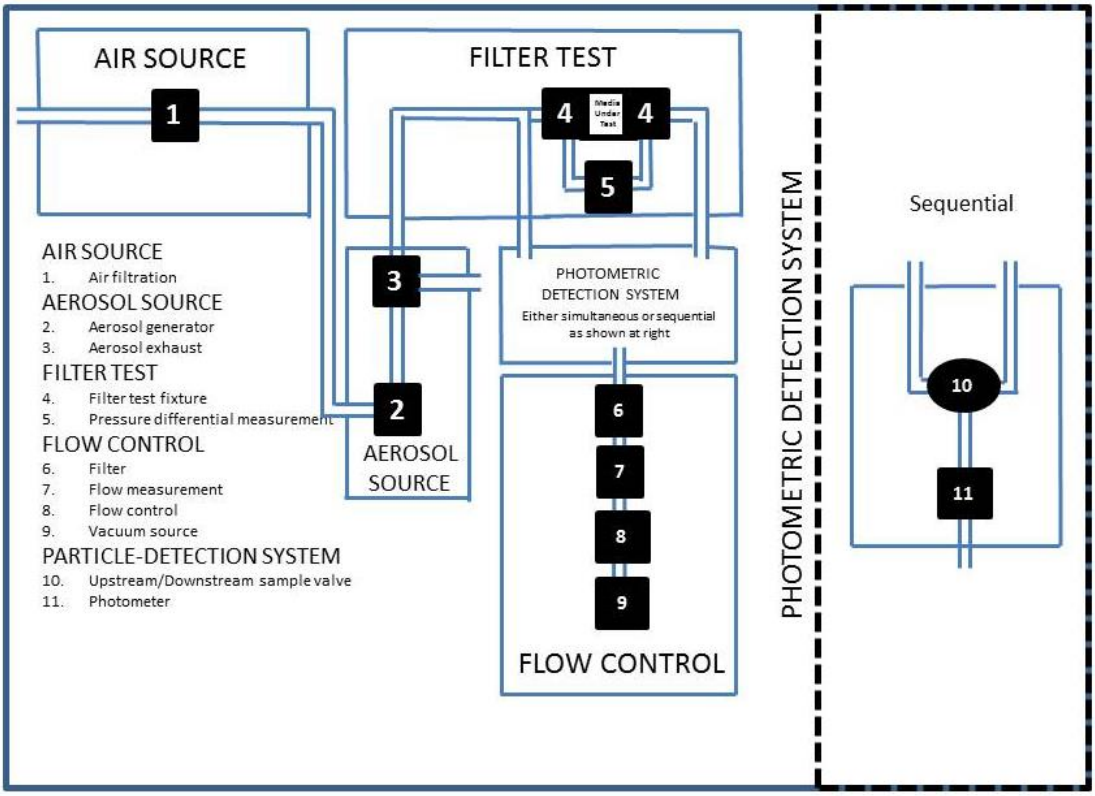

Figure 1—Basic components for the HEPA filter media penetration test—photometric method.

4.3.1 Test components—photometric method

a) Air filtration (Figure 1, item 1)

Test air should be cleaned to a particulate contamination level of less than 1% of the challenge aerosol concentration prior to mixing the air with test aerosol. Filtration with HEPA filters is recommended.

b) Airflow measuring device (Figure 1, item 3)

Airflow should be maintained to within ±5% of specified test flow for the duration of the procedure.

c) Device for flow control (Figure 1, item 8)

The precision of the flow measuring device should be ±3% or better.

d) Media holding device—test fixture or chuck (Figure 1, item 4).

For evaluation of filter media a circular test area of 100 cm^2 ±2 % is called out in ASTM D2986.

e) Aerosol material

Traditionally, DOP has been the challenge aerosol material for testing filters with photometers. However, due to the potentially adverse health effects of DOP, regulatory health organizations have accepted PAO as a substitute for DOP. Another possible alternative for this test is DOS/DEHS. 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.

NOTE: Safety Data Sheets (SDS) must be available for all materials that are used, and the health risks of using the materials in aerosol form must be assessed.

The test aerosol should have a shape factor of less than 2, and an index of refraction with a real part between 1.45 and 1.60 and negligible imaginary part, when an alternate aerosol material is used. The vapor pressure should be

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sufficiently low that diameter changes throughout the test system do not exceed 10%. The use of aerosol materials that do not meet these specifications may lead to erroneous penetration measurements.

i) Aerosol source

Although no such arrangement is illustrated in Figure 1, it is common practice when changing the test media to stop aerosol flow from the aerosol source to the test fixture (chuck).

1) Aerosol generator (Figure 1, item 2)
The aerosol generated is methodology specific, and is based on controlled condensation of vapor created using the chosen aerosol material to produce the desired aerosol characteristics. The aerosol generator should be capable of producing a stable aerosol concentration that is sufficient to permit statistically valid conclusions to be drawn.

2) Aerosol source output rate (Figure 1, item 7)
When testing filter media, the aerosol concentration upstream of the test medium should be 100 ±20 µg/L of DOP when measured gravimetrically (reference NIOSH Manual of Analytical Method, Procedure 500 for necessary steps) while maintaining a 29 ±1.0° refractive index as measured by an owl particle size meter. Concentration is controlled by increasing or decreasing the liquid reagent temperature.

j) Sampling and sample lines

The means of sampling should be designed to provide representative samples. The sampling tubing should provide as direct a sample path as possible and be as short as possible.

Turbulence should be avoided and the use of valves, restrictions, and bends in sampling lines minimized.

k) Photometer (Figure 1, item 11)

Photometers should be capable of responses independent of particle size in the 0.1-to-3.0-µm size range—that is, their detection efficiency should be constant in this size range. In general, it is good practice to select photometers that have been calibrated according to IEST-RP-CC013.

The equipment should be capable of repeatedly and accurately measuring the concentrations upstream and downstream of the filter. The zero background level (unadjusted straylight) of the photometer should be less than 0.1% of the maximum concentration being measured.

4.3.2 Test procedure—photometric method

Testing HEPA filter media using the photometric method may be accomplished with either a linear or a logarithmic forward-light-scattering photometer.

a) Preparation for photometric test

Prior to performing the photometric procedure with a forward-light-scattering photometer, the following steps should be taken:

1) Turn on the aerosol generator. Wait for the unit to reach operating temperature and the aerosol concentration to stabilize.

2) Adjust the airflow rate to the desired setting. The recommended face velocity is 5.33 cm/sec (9.8 ft/min), although a different face velocity may be used as agreed upon by the customer and supplier.

3) Place the photometer in the 100% range and, with an empty test fixture, measure the upstream aerosol concentration and adjust the gain potentiometer for 100% unit response.

4) Place the photometer in the 0.1% range and, with particle-free sample air being drawn through a zero-reference, adjust for 0% unit response using the straylight compensation potentiometer.

b) Photometric test method

The following procedure is recommended when using a forward-light-scattering photometer:

1) Place the test sample of the filter media in the test fixture (chuck) and close.

2) Measure the airflow resistance (see 4.1).

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