UCRL-AR-133354 Rev 2

HEPA Filter and In-place Leak Testing Standard

Gordon Miller
George Fulton
Werner Bergman

U.S. Department of Energy
Lawrence Livermore National Laboratory

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Preface

The HEPA Filter and In-place Leak Testing Standard is one of several local Lawrence Livermore National Laboratory (LLNL) environmental, safety, and health standards that was prepared during the Work Smart Standards Closure Process to address areas not adequately covered by Department of Energy (DOE) orders or national consensus standards. The original version was reviewed on March 19, 1999 and peer reviewed by May 14, 1999. Questions or comments about this revised standard should be addressed to the Chemical and Biological Safety Section in the Hazards Control Department.

Lawrence Livermore National Laboratory

HEPA Filter and In-place Leak Testing Standard

1.0 Scope

This local standard establishes LLNL specifications that supplement the national standards (referenced in Section 2.0) for the operation of high efficiency particulate air (HEPA) filters when installed in ventilation systems used for worker, public, and environmental protection from significant exposure to highly hazardous (e.g., radioactive, carcinogenic, beryllium, select agents) aerosols. The supplemental specifications define the maximum pressure drop, maximum age, and in-place leakage that can be allowed before the filters must be replaced. This local standard also identifies procurement specifications for HEPA filters.

1.1 Limitations of this Standard

This local standard and the documents referenced in Section 2.1 do not apply to filters installed on glove boxes to prevent contamination of a length of duct separating the glove box and the building's HEPA filters ("housekeeping filters"), HEPA filters in vacuum cleaners, HEPA filters installed in waste containers, or HEPA filters used in clean rooms or laminar flow benches to protect work pieces. HEPA filters in ventilation systems that are not used to protect workers, the public, and the environment from significant exposure to highly hazardous aerosols are exempt from this local standard. This local standard and all the referenced national standards do not apply to HEPA filters that are addressed separately in the LLNL Work Smart Standard Set, (i.e., Class II biological safety cabinets, as addressed in NSF 49, and asbestos abatement).

1.2 Use of this Standard

This local standard and the referenced national standards address in-place leak tests and replacement of HEPA filters installed in ventilation systems designed to remove highly hazardous aerosols from effluent streams. The referenced standards in Section 2.1 shall be used as the primary standards for HEPA filters, including their installation in housings and in-place testing. A risk-based graded approach will be used to determine the priority for replacing existing HEPA filters that are not in compliance with this standard.

2.0 Referenced Documents

2.1 Generally Applicable Documents

- American Society of Mechanical Engineers (ASME), "Nuclear Power Plant Air-Cleaning Units and Components," Section 5.6, "Filter Housing," ASME N509-1989 (1989). This ASME N509 standard applies only to new filter plenums and as a guide to upgrading existing filter plenums. The ASME N509 standard does not apply to side-access filter housings but can be used as a guide for them.
- ASME, "Testing of Nuclear Air-Cleaning Systems," Section 10, "HEPA Filter Bank In-Place Test," ASME N510-1989.
- DOE-STD-1027-92, change 1, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," (1997).
- DOE-STD-3020-97, "Specification for HEPA Filters Used by DOE Contractors," (1997).
- DOE-STD-3022-98, "DOE Standard: DOE HEPA Filter Test Program," (1998).
- Lawrence Livermore National Laboratory, HVAC Systems in Nonreactor Nuclear Facilities, UCRL-AR-133352 Rev 1, (1999). This local standard applies only to LLNL nuclear facilities.
- Lawrence Livermore National Laboratory, "Maximum HEPA-filter Life," UCRL-AR-134141, (1999).
- Institute of Environmental Sciences and Technology (IEST) Recommended Practice IEST-RP-CC001.3, "HEPA and ULPA Filters,"(1993).
- Institute of Environmental Sciences & Technology, IEST-RP-CC034.1, "HEPA and ULPA Filter Leak Test", 1999.

2.2 Other Referenced Documents

- American Society of Mechanical Engineers (ASME), "Code on Nuclear Air and Gas Treatment," Section FC, "HEPA Filters," ASME AG-1-1997 and revisions adopted in 1996.[1]

[1] Military standards MIL-F-51068, "Filters Particulate (High Efficiency Fire Resistant)," MIL-F-51079, "Filter Media, Fire Resistant, High Efficiency," and MIL-F-51477. "Military Specification for Filters, Particulate, High Efficiency, Biological Use, General Specification for," referenced in the DOE and IEST standards have all been cancelled either without replacement, or have been replaced by ASME AG-1. Appendix FC-I, "Filter Media Fire-Resistant, High Efficiency," is derived from MIL-F-51079D and is a mandatory appendix to AG-1, Section FC.

- National Sanitation Foundation, Standard No. 49, "Class II (Laminar Flow) Biohazard Cabinetry," (1987).

3.0 Terms and Definitions

Challenge aerosol: An aerosol generated during the test for in-place testing of installed HEPA filter systems. The aerosol is polydisperse with a light scattering mean droplet diameter of 0.7-µm. The original challenge aerosol used was dioctyl phthalate (DOP); however, other equivalent nontoxic liquids are commonly used. LLNL currently uses poly alpha olefins (PAO)[2].

HEPA filter: High-efficiency particulate air filter**.** A throwaway, pleated, unreinforced media, dry filter with a rigid casing enclosing the full depth of the pleats. The filter has a minimum efficiency of 99.97% when tested with an aerosol of essentially monodispersed 0.3-µm challenge aerosol.

Leakage: Passage of challenge aerosol past the HEPA filter between the upstream and downstream sample ports as defined in the following equation:

$$L = 100\left(\frac{C_d}{C_u}\right)$$

Where

L = percent leakage
C_d = downstream concentration of aerosols
C_u = upstream concentration of aerosols

Pressure drop: The differential static pressure across the filter in units of inches, water gauge.

Significant exposure: The amount of hazardous aerosols that may subject workers, the public, or the environment to levels above recognized exposure standards, regulatory emission levels, or Laboratory requirements.

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[2] Both ASME N509-1989, AMSE N510-1989 and IEST-RP-CC001.3 provide the same specification for a DOP test aerosol:

An aerosol with the following approximate light-scattering mean-size distribution:
99+%, less than 3.0 µm
50+%, less than 0.7 µm
10+%, less than 0.4 µm

PAO is physically identical to DOP for purposes of mechanical aerosol generation; thermal aerosol generators are factor adjusted to properly function with PAO instead of DOP. The photometers have been factor adjusted to quantitatively respond to PAO rather than DOP.

Stairmand disk: A plate occupying the central half of the area of a duct oriented so it is perpendicular to the direction of airflow. It is used to induce turbulence and is usually pivoted so it is oriented in this manner only during filter testing. The "disk" in a rectangular duct will be rectangular.

Units: any self-consistent set of units for pressure, flow, and concentration can be used. Conventional units for ventilation systems are inches of water for pressure and feet per minute (linear) or cubic feet per minute (volumetric) flow. Conventional units for the aerosol penetrometer are percent, with the instrument adjusted to read 100% for the challenge aerosol concentration.

4.0 HEPA Filter Operation Specifications

4.1 Pressure Drop Limit

HEPA filters shall be removed from service before the pressure drop across the filter exceeds five inches of water when normalized to the rated airflow of the HEPA filter. To determine the normalized pressure drop, the measured pressure drop must be corrected for deviations from the rated airflow of the HEPA filter as follows:

$$DP_{nor} = DP_{meas}\left(\frac{F_{rated}}{F_{meas}}\right)$$

Where

DP_{nor} = normalized pressure drop
DP_{meas} = measured pressure drop
F_{rated} = rated air flow
F_{meas} = measured air flow for HEPA filters

The maximum airflow through the HEPA filter must not exceed its maximum rated flow.

4.2 Age Limit

Currently, there are no regulations or standards concerning the service life of HEPA filters; however, LLNL has set age limits based on the best available information. This standard establishes the requirement that HEPA filters shall be replaced ten years after the date of manufacture. The exceptions to this requirement are as follows:

- Any such filter that has become soaked or which could have become soaked, as from the activation of an in-duct water sprinkler or from spraying water directly on the filter, shall be replaced promptly.

- Any such filter that could become soaked, as from the activation of an in-duct water sprinkler, shall be replaced within five years of the date of manufacture.
- Any such filter that may be exposed to potentially damaging chemicals shall be replaced at an interval to be determined on a case-by-case basis, but in all cases not to exceed 5 years from date of manufacture.

If the manufacturing date is not available, HEPA filters shall be replaced after five or ten years, as applicable, from the date of original certification at a DOE filter test facility.

5.0 Leak Testing

Filters systems shall be designed and installed so the system can be quantitatively leak tested. The injection port (if necessary) and sampling ports shall be of sufficient size (nominal 1/2 inch in diameter) for insertion of the output line from the aerosol generator or photometer probe. There are two types of leak tests that are permitted: 1) total leak test and 2) scan leak test. For radioactive applications, only the total leak test is allowed. For all other applications, either method is allowed. Both methods require qualification of the testing system to ensure uniform challenge concentration. The total leak test also requires the downstream sample be qualified to ensure the concentration is uniform. The scan test apparatus must be qualified to be capable of traversing the entire filter sealing gasket and the perimeter of the filter support/duct housing structure in addition to the filter. Each test system is qualified only once prior to conducting periodic leak tests. The total leak test is prescribed in ASME N510-1989, Section 10, and the scan leak test is prescribed in IEST-RP-CC034.1.

5.1 Qualification to Ensure Uniform Challenge Concentration for Both Tests

5.1.1 Access to Inject Challenge Aerosol

Access is required to permit the injection of challenge aerosol upstream of the filter. The aerosol can be injected at a device served by the filter system or via a port installed in the ductwork upstream of the features that accomplish the tasks listed in Sections 5.1.2 and 5.1.3.

5.1.2 Mixing Devices Upstream of the Filter

Proper configuration is required to mix the challenge aerosol thoroughly. This can be accomplished through elbows installed in the system ductwork, other installed devices that are designed to induce turbulence, or by adding a device to create mixing by inducing turbulence, such as a Stairmand disk.

5.1.3 Adequate Duct Length After Mixing Devices

Adequate duct length is required to allow the flow and concentration of aerosol to become uniform before the upstream aerosol measurement location.

5.2 Qualification to Ensure Uniform Downstream Concentration for Total Leak Test

Thorough mixing is required for any leaking aerosol downstream from the filter. This is difficult because the airflow leaving a HEPA filter is laminar. Inducing turbulence in the downstream airflow is one method that produces mixing. There are two approaches for achieving this.

5.2.1 Uniform Aerosol Concentration Using Duct Length

Adequate duct length is required to allow the air velocity and the aerosol concentration to become uniformly distributed. This is ensured by placing the downstream sampling location ≥7.5 equivalent duct diameters downstream from the closest upstream source of turbulence. This ensures the aerosol concentration is uniform across the duct and the measurement is representative of leakage through the system.

5.2.2 Uniform Aerosol Concentration Using Engineered System

An engineered turbulence induction and sampling manifold system which collects samples at multiple points downstream of all portions of the filter after mixing for concurrent measurement of the average concentration is an alternative. This is accomplished using a segment inserted downstream of the filter that does not need to be ≥7.5 duct diameters long.

5.3 Qualification Test to Demonstrate the Scan Test Can Measure All Leaks

Scanning one inch from the downstream ("clean") face of the filter is an alternative method that eliminates the need to mix leaks on the downstream side, but it requires specific equipment that shall be installed in the filter system at the time the system is built. The scan test apparatus must be qualified by demonstrating it can measure leaks along the entire filter sealing gasket and the perimeter of the filter support / duct housing structure as well as leaks in the filter itself. A typical scanning system consists of one or more funnel shaped collectors attached to an apparatus that can traverse over the duct section at one inch from the face of the HEPA filter in an overlapping fashion as prescribed in IEST-RP-CC034.1.

6.0 Acceptance Criteria for In-Place Leakage Tests

6.1 Criteria for Total Leak Test

HEPA filters covered by this local standard using the total leak test are subject to annual in-place leakage tests as prescribed in ASME N510-1989, Section 10. The HEPA filter and its installation are acceptable if the percent leakage is equal to or less than 0.03% or other value less than 0.05% and specified in an approved Technical Safety Requirement or other appropriate safety basis document. If the in-place leakage exceeds 0.03% or other specified value and cannot be adjusted by correcting the sealing clamps, the HEPA filter shall promptly be replaced.

6.2 Criteria for Scan Leak Test

HEPA filters covered by this local standard using the scan leak test are subject to annual in-place leakage tests as prescribed in Institute of Environmental Sciences and Technology (IEST) Recommended Practice IEST-RP-CC034.1, "HEPA and ULPA Filter Leak Tests." For these tests, the maximum allowable leakage, measured anywhere on the downstream face of the filter, shall be 0.01%. If the in-place scan test exceeds 0.01% and cannot be adjusted by correcting the sealing clamps, the HEPA filter shall promptly be replaced.

7.0 Filter Stages

The number of stages in a HEPA filter system shall be addressed before design begins in a hazard assessment (e.g., an Authorization Basis document or other analysis in which the potential discharges of, exposures to, and degree of filtration for an aerosol are rigorously considered). Both stages of a filter system shall be testable, as specified in Section 5 of this document, should a two stage system be selected,

8.0 Construction

Air cleaning systems used in nuclear facilities shall be designed in accordance with American Society of Mechanical Engineers (ASME), *Nuclear Power Plant Air-Cleaning Units and Components,* "Filter Housing," ASME N509-1989, Section 5.6. This ASME N509 standard applies only to new filter plenums and as a guide to upgrading existing filter plenums. The ASME N509 standard does not apply to side-access filter housings but can be used as a guide for them.

Other systems shall meet the requirements specified in specific safety analysis reviews and other safety documents on a case-by-case basis.

Resistance to natural phenomena is addressed in design specifications for equipment in the design stage and is not addressed here.

9.0 Procurement Specifications

For purposes of this standard, HEPA filters for nuclear facilities shall meet the specifications of DOE-STD-3020-97. Other facilities can use HEPA filters that comply with either DOE-STD-3020-97 or IEST Recommended Practice IEST-RP-CC001.3, "HEPA and ULPA Filters", Type E.