# Accelerated Aging of Nuclear Grade HEPA Media: Test Plan Design and Analysis

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## Abstract

There is limited scientific information related to supporting the establishment of a set lifetime and/or shelf life of nuclear grade High Efficiency Particulate Air (HEPA) filter media used in current and future nuclear facilities sites. Removing operational HEPA filters too soon is cost prohibitive to facilities, but prolonged use after the filter has lost any functionality carries risks to workers, public, and environmental safety. This has been discussed for several decades, but information is still needed to completely address the issue. The Institute for Clean Energy Technology (ICET) is developing a test plan to conduct a study to accelerate the natural aging process of HEPA media through an accelerated testing technique. The methodology for exposure process will include using elevated temperatures for extended periods of time. The accelerated aging studies will also include exposure of accelerated aged and naturally aged HEPA media to ozone and corrosive aerosol particles. ICET will use a full suite of analytical techniques to extensively evaluate the chemical and physical characteristics of the exposed and unexposed, naturally and accelerated aged HEPA filter media. This study will be divided into six phases. An overview of the procedures, techniques, instrumentation, and analysis process that will be used during each phase of this study are presented here.


## Accelerated Aging

Accelerated aging simulates the natural aging process of a material by introducing elevated exposure stresses for extended time periods. Chemical degradation is accelerated by exaggerating various stresses and testing the extent to which the properties have changed. Cycles of changing conditions can be run in order to accelerate the environmental effects of natural fluctuations on a material in the course of normal use or storage.

Accelerated aging exposure for polymer degradation reactions are based on Arrhenius rate law calculations.

Objectives of Accelerated Aging of HEPA Media Study:

- Accelerated aging sets of HEPA filter media in high performance laboratory ovens set at the elevated temperature and within a relative humidity range presented to simulate HEPA media that has been aged 1 to 15 years.
- Naturally aging sets of media in an environmental room set at ambient temperature and within same relative humidity range for the same number of days that the aged media placed in the temperature humidity chambers.
- Perform evaluations by using ICET's analytical techniques.
- Analyze data and perform modeling to support results.
- Expose HEPA media to low concentrations of acidic aerosols. Accelerated aging exposed media in ovens set at elevated temperatures to simulate media that has been aged 3, 6, 9, 12, 15, and 18 months.
- Perform evaluations on exposed media at months 3, 6, 9, 12, 15, and 18 of simulated aging by using analytical techniques.
- Analyze data and perform modeling.
- Create a report and present results.

Accelerated Aging of Materials:

- An Accelerated Aging Factor (AAF), which is an estimated or calculated ratio of the time to achieve the same level of physical property change as a material stored at real time conditions, can be calculated by using the following equation:

$$AAF = Q_{10}^{[(T_{AA} - T_{RT})/10]} \qquad \text{Equation 1}$$

where

$T_{AA}$ = the accelerated aging temperature (°C),
$T_{RT}$ = the ambient room temperature (°C) and
$Q_{10}$ = an aging factor for 10 °C increase or decrease in temperature

- The AAF is based on the 10-degree rule which states that for each 10-degree (°C or K) rise in temperature, the specific reaction rate doubles. The AAF is used to calculate the Accelerating Aging Time (AAT).

$$AAT = {}^{Shelf\ Life}/_{AAF} \qquad \text{Equation 2}$$

## Phases of Accelerated Aging Project

Simple random sampling is performed to assemble each sample set. One set includes all media needed for analytical techniques and imaging.

Phase 1. Baseline analytical testing of new HEPA media and media exposed to acidic aerosols, basic aerosols, and/or ozone.

Phase 2. Accelerated aging and naturally aging of new HEPA media.

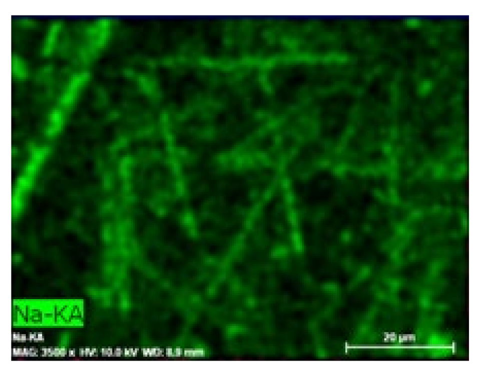
Phase 3. Analytical testing of accelerated and naturally aged media from Phase 2.

Phase 4. Expose aged media from Phase 2 to high concentrations of acidic aerosols, basic aerosols and/or ozone.
Perform analytical testing on exposed media.

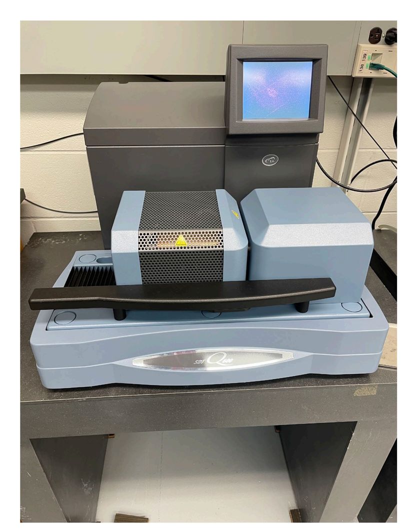
Phase 5. Expose media to low concentrations of acidic and/or basic aerosols. Accelerated and naturally aging media.

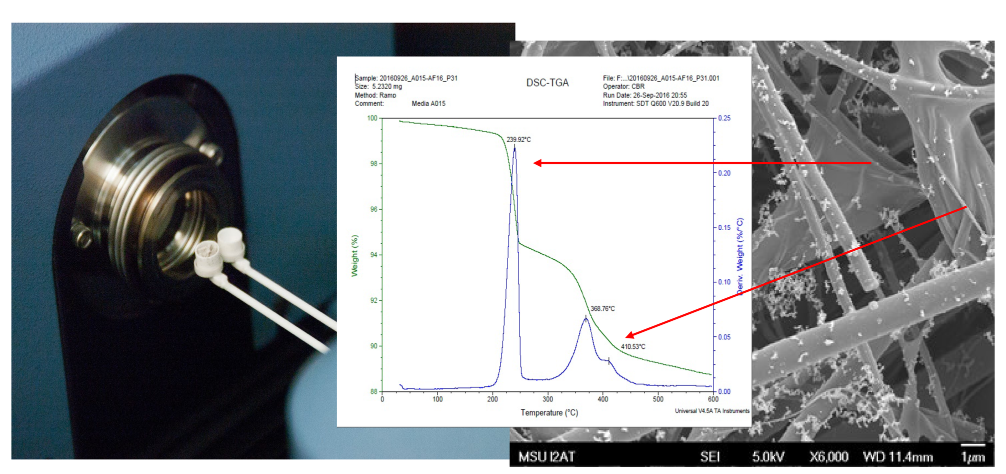
Phase 6. Analytical testing of accelerated and naturally aged media from Phase 5.

## Analytical Techniques and Instrumentation



- Airflow Resistance and Particle Penetration
  - TSI Certitest Automated Filter Tester
- Tensile Strength and Percent Elongation Testing of Wet and Dry Media
  - Thwing-Albert Vantage NX Universal Tester
- Water Repellency Testing
  - ICET Hydrostatic Tester
- Media Thickness Testing
  - Thwing-Albert ProGage Thickness Tester
- Thermal Analysis (TGA, DSC, SDT)
  - TA Instruments SDT Q 600
  - TGA 5500
- Combustible Materials Determination
  - TGA 5500
- Scanning Electron Microscopy (SEM)
  - JEOL 6500 FE
  - Inca and Image J Software
- Energy-Dispersive X-Ray Spectroscopy (EDX)
  - JEOL 6500 FE
  - Inca Software

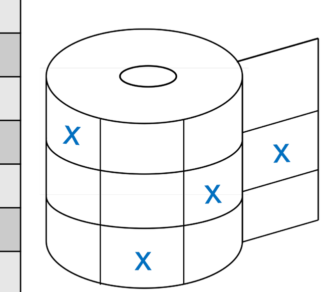


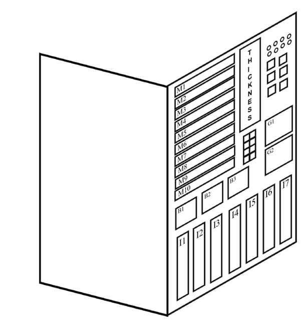


## Accelerated Aging Ovens

Table 1. Exposure of Media to Elevated Temperatures for Accelerated Aging

| Oven Temperature (°C) | Relative Humidity Range (%) | Accelerated Time in Chamber (Days) | Accelerated Age of Filter Media at Testing (years) |
|---|---|---|---|
| 60 | 10 to 35 | 28 | 1 |
| 50 | 10 to 35 | 56 | 1 |
| 60 | 10 to 35 | 70 | 2.5 |
| 50/60 | 10 to 35 | 140 | 2.5/5 |
| 60 | 10 to 35 | 211 | 7.5 |
| 50/60 | 10 to 35 | 281 | 5/10 |
| 60 | 10 to 35 | 351 | 12.5 |
| 50/60 | 10 to 35 | 421 | 7.5/15 |
| 50 | 10 to 35 | 562 | 10 |
| 50 | 10 to 35 | 702 | 12.5 |
| 50 | 10 to 35 | 843 | 15 |

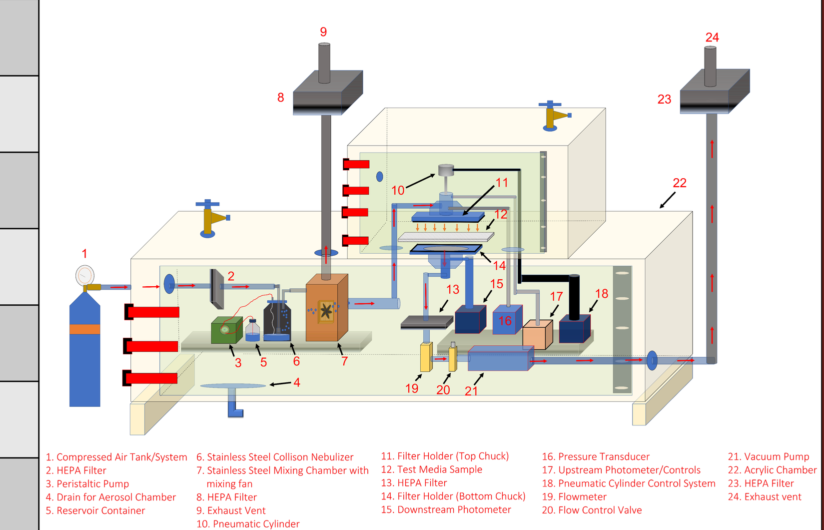




## Aerosol Exposure System

Table 2. Acidic and Basic Aerosols Exposure Parameters for Media

| Acids or Bases Used | Concentrations Used ($mg/m^3$) | pH | Length of Exposure (minutes) | Chamber Temperature (°C) | Relative Humidity (%) | Supply Air | Air Flow Rate |
|---|---|---|---|---|---|---|---|
| **Hydrochloric Acid** | $1{\times}10^3$ to $2{\times}10^8$ | 0 to 6 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Hydrofluoric Acid** | $1{\times}10^3$ to $2{\times}10^8$ | 0 to 6 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Nitric Acid** | $1{\times}10^3$ to $2{\times}10^8$ | 0 to 6 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Phosphoric Acid** | $1{\times}10^3$ to $2{\times}10^8$ | 0 to 6 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Sulfuric Acid** | $1{\times}10^3$ to $2{\times}10^8$ | 0 to 6 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Sodium Hydroxide** | $1{\times}10^3$ to $2{\times}10^8$ | 8 to 14 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Potassium Hydroxide** | $1{\times}10^3$ to $2{\times}10^8$ | 8 to 14 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Strontium Hydroxide** | $1{\times}10^3$ to $2{\times}10^8$ | 8 to 14 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Cesium Hydroxide** | $1{\times}10^3$ to $2{\times}10^8$ | 8 to 14 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |
| **Lithium Hydroxide** | $1{\times}10^3$ to $2{\times}10^8$ | 8 to 14 | 10, 30, and 60 | 23 | 10 to 35 | Compressed Air | TBD |



## Ozone Environmental Exposure Chamber

Table 3. Ozone Exposed to Media

| Ozone Concentration (ppm) | Length of Exposure (minutes) | Chamber Temperature (°C) | Relative Humidity (%) | Supply Air |
|---|---|---|---|---|
| 0.025 | 60, 300, and 600 | 23, 30, and 40 | 10 to 35 | oxygen |
| 0.050 | 60, 300, and 600 | 23, 30, and 40 | 10 to 35 | oxygen |
| 0.10 | 60, 300, and 600 | 23, 30, and 40 | 10 to 35 | oxygen |
| 2.50 | 6, 30, and 60 | 23, 30, and 40 | 10 to 35 | oxygen |
| 5.00 | 6, 30, and 60 | 23, 30, and 40 | 10 to 35 | oxygen |
| 10.00 | 6, 30, and 60 | 23, 30, and 40 | 10 to 35 | oxygen |

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