Waste Treatment Plant Project

Development of High Strength HEPA Filters for Hanford's Waste Treatment Plant (WTP)

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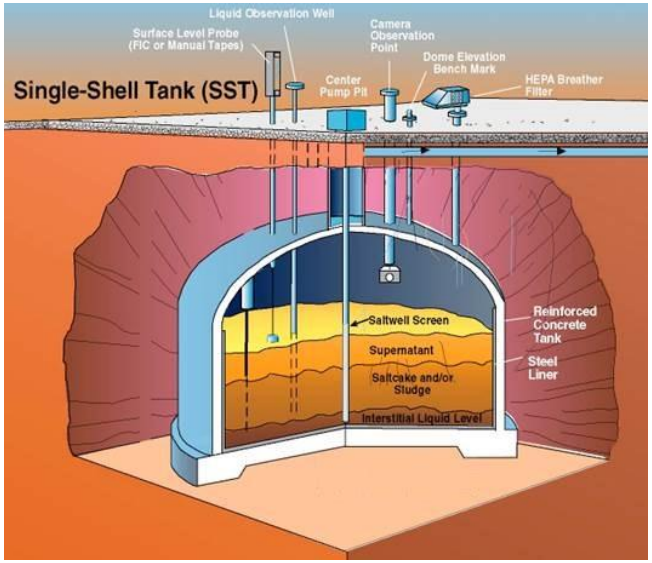
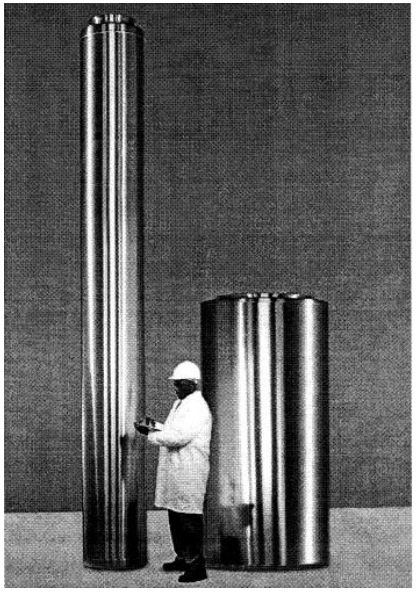
June 24, 2014

U.S. DEPARTMENT OF ENERGY | Bechtel National, Inc. | URS

Introduction

- The Hanford Waste Treatment and Immobilization Plant (WTP) is a complex of waste treatment facilities that will convert radioactive liquid waste into a stable glass form.
- Bechtel is designing, building, commissioning and starting up the WTP for the DOE Office of River Protection (ORP).
- The waste treatment facilities will immobilize the 56 million gallons of radioactive liquid waste stored in 177 aging underground tanks at the Hanford Site.





Introduction

- The Hanford Site occupies 586 square miles and is located along the Columbia River; North of the city of Richland, Washington.
- The WTP will be constructed at the East end of the 200 East Area of the Hanford Site.

Introduction

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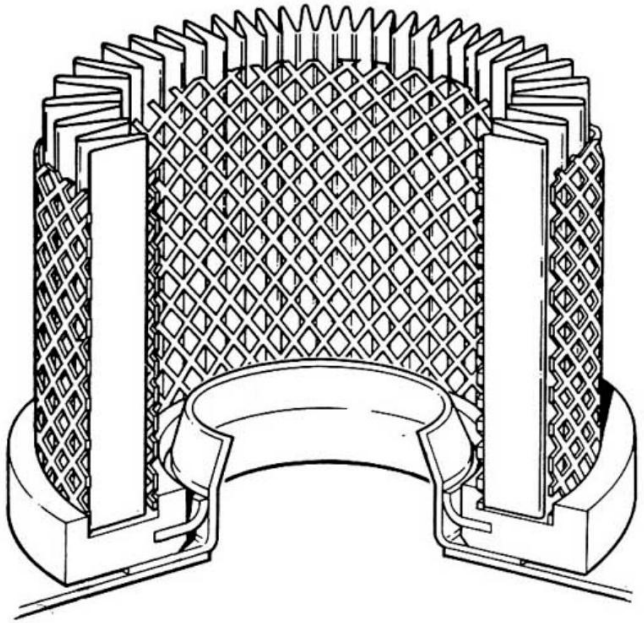
Introduction

- It is estimated that the WTP will require 797 radial flow HEPA filters for normal operation (576 Safe Change and 221 Remote Change).

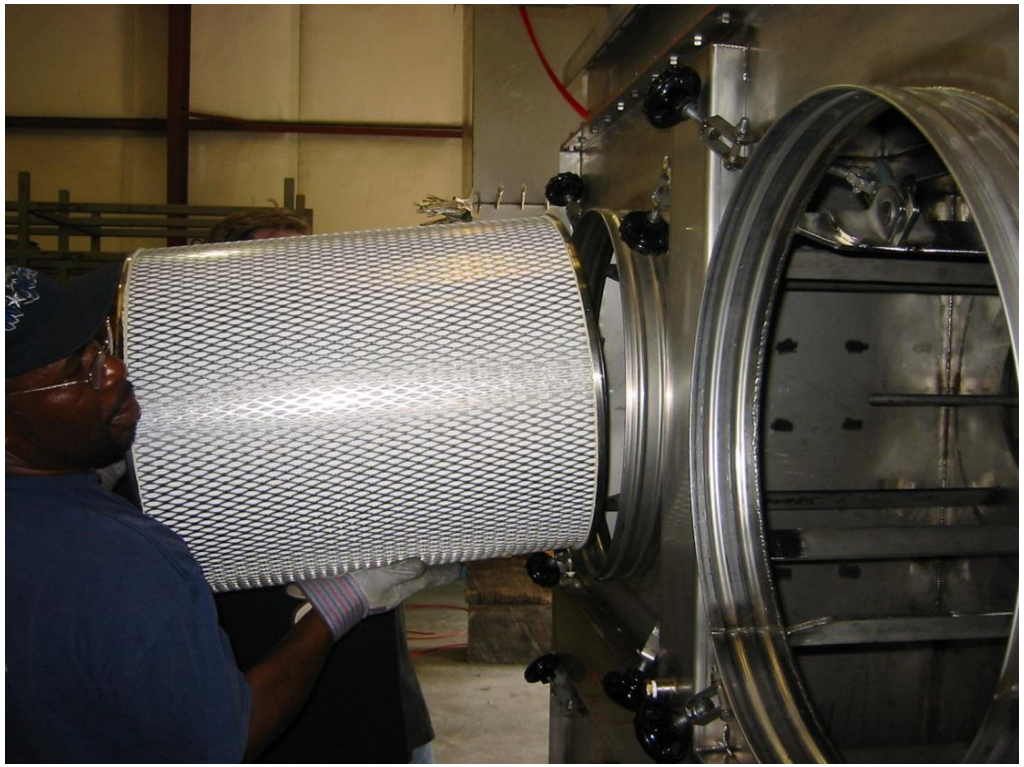
Photo of a Remote Change HEPA filter design



Cut away Illustration of generic radial filter design

Introduction

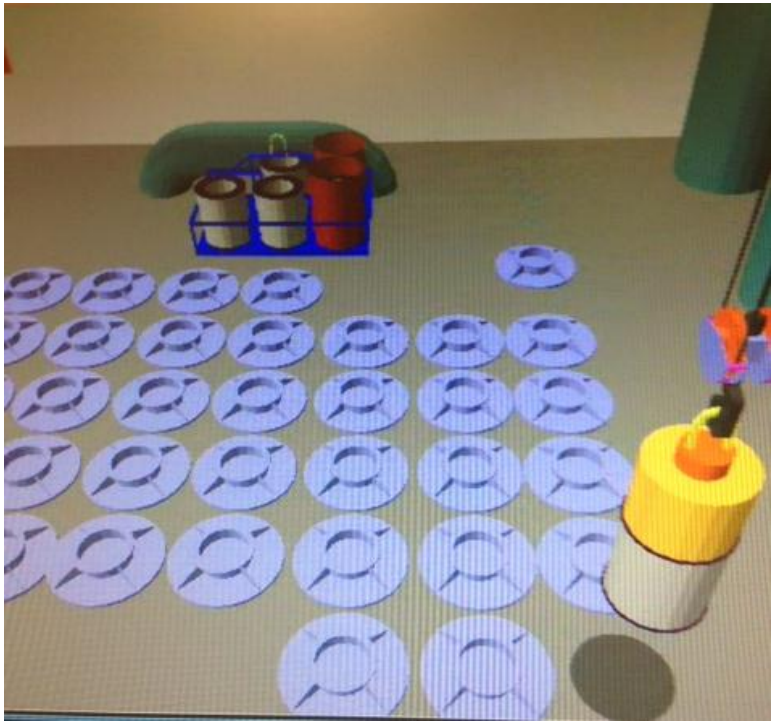
- Safe Change Radial Flow HEPA Filter



- Safe Change HEPA filters are manually installed in the filter housing.
- Fiberglass filter media types weigh less than metal fiber media and are preferred for Safe Change applications.

Introduction

- Remote Change Radial Flow HEPA Filter
- Remote Change HEPA filters are installed by an operator manipulating a crane from a control room.



Problem Statement

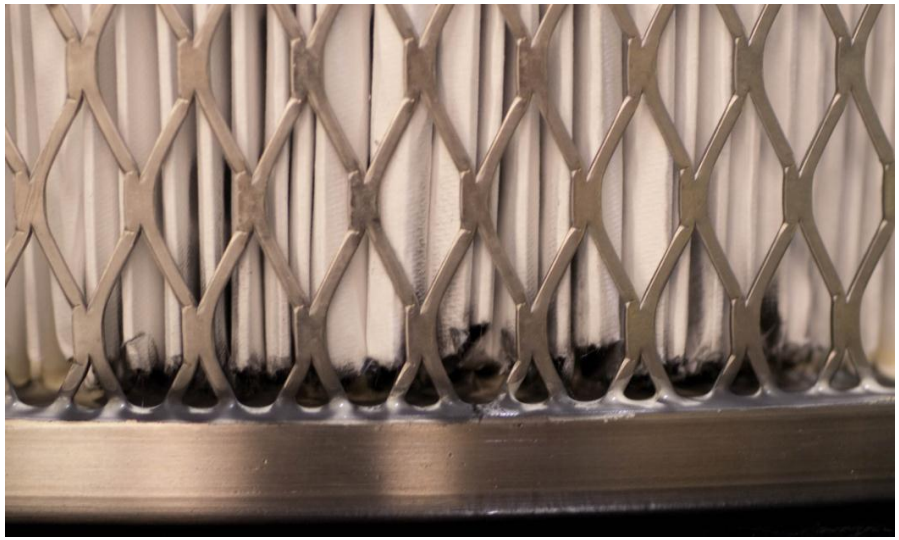
- The WTP must comply with ASME AG-1.
- Performance criteria are being imposed on WTP HEPA filters to meet combined conditions of high temperature and relative humidity when the filter is loaded to 4 inches WC.
- The above criteria is beyond what ASME AG-1, Section FK requires.
- ASME AG-1, Section FK does not address requirements for these combined conditions.

Problem Statement

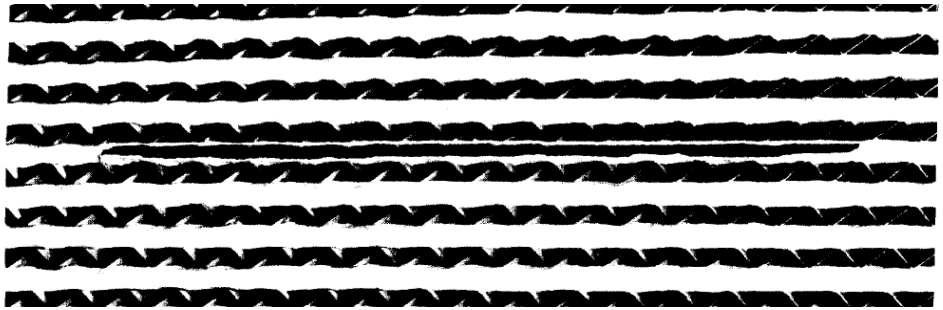
- Two major HEPA filter failure modes:
  - Loss of efficiency due to medium tears
  - Loss of flow capacity due to pleat collapse
- Current ASME AG-1 qualification tests consider failure to be loss of filter efficiency, and not the loss of flow capacity.
- HEPA filters are inherently weak under normal conditions and become significantly weaker when exposed to higher temperatures and high humidity.

Problem Statement

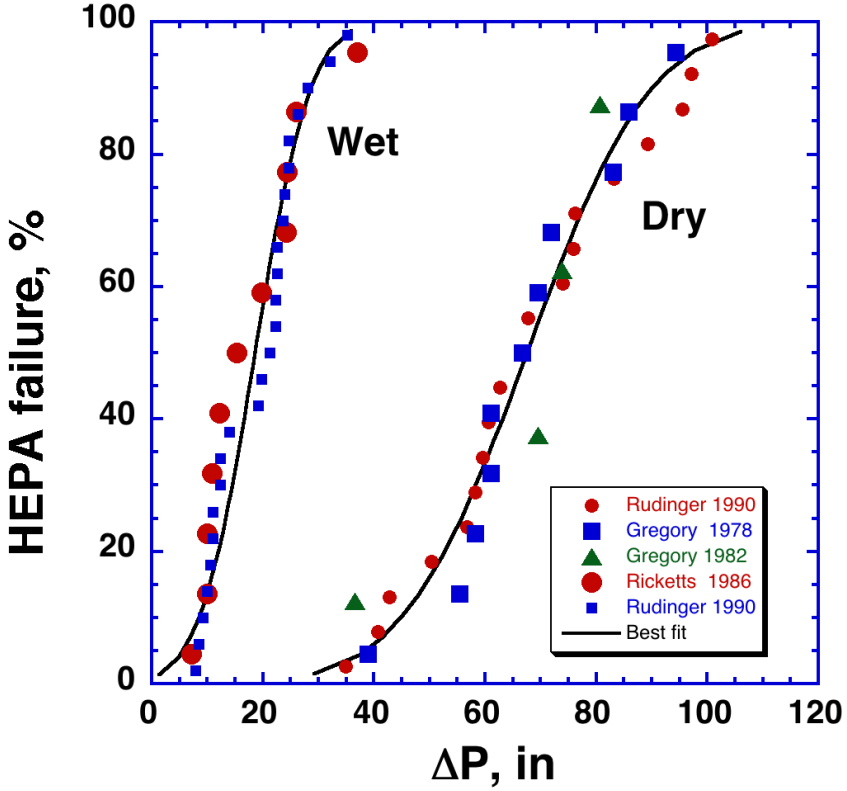
- Medium tear failure occurs due to weak tensile strength.



Tear near sealant due to filter pack bending

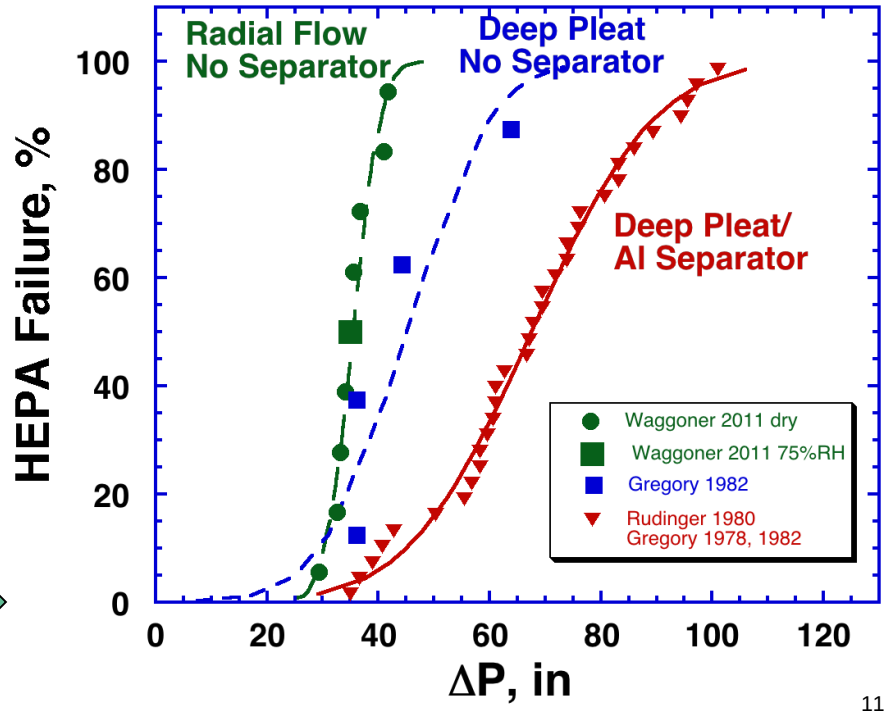


Tear along pleat due to pleat ballooning



Media tears occur at lower pressures when wet.

The failure threshold is due to the minimum medium tensile strength in AG-1.

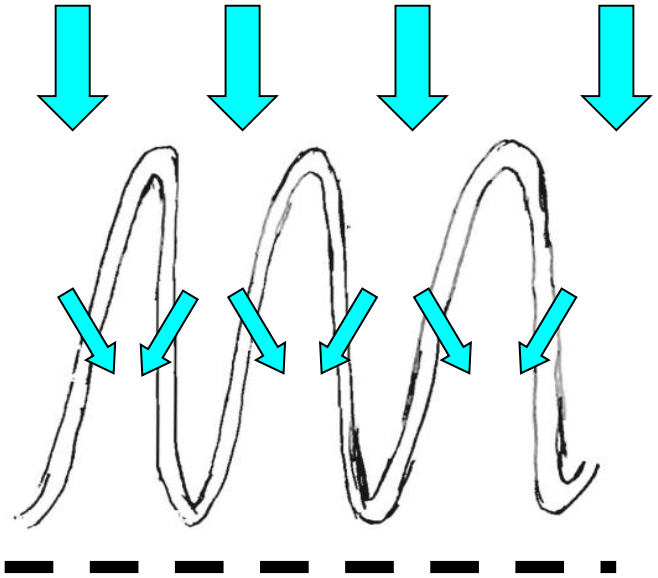


Problem Statement

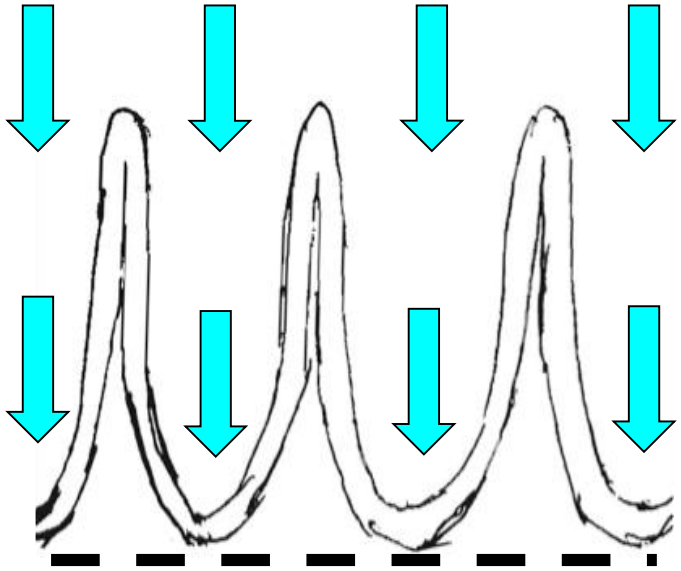
- Pleat collapse and pack distortion can occur with wet media.

Problem Statement

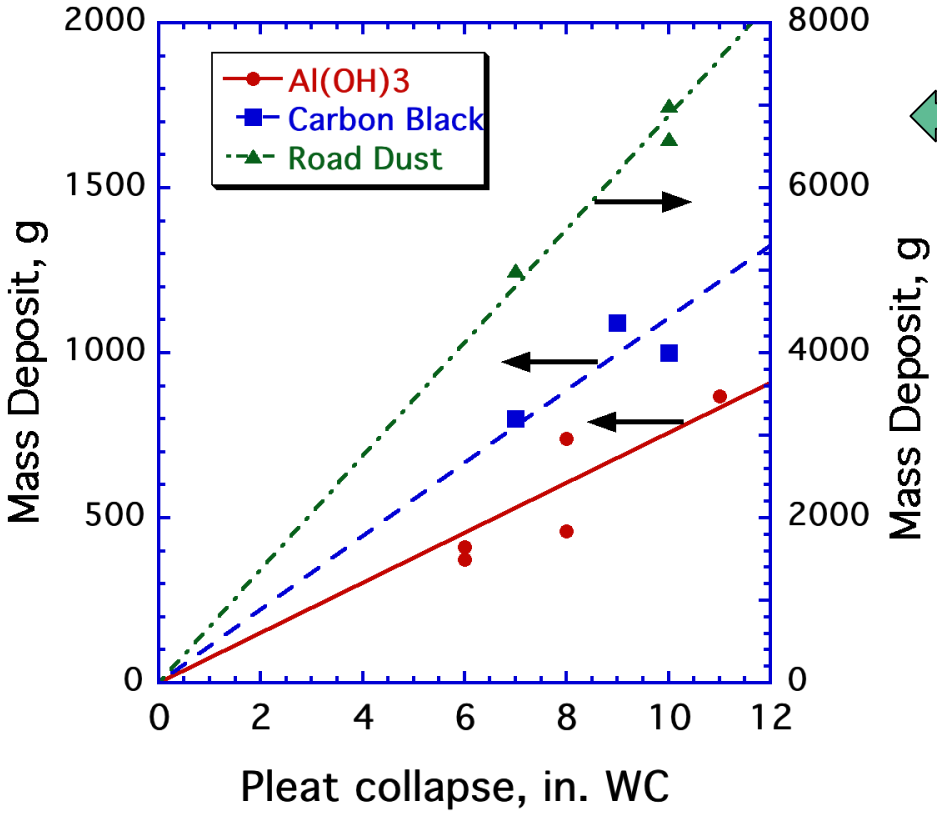
- Pleat collapse forces air through smaller area increasing filter DP and decreasing particle loading.



Air flows through entire media

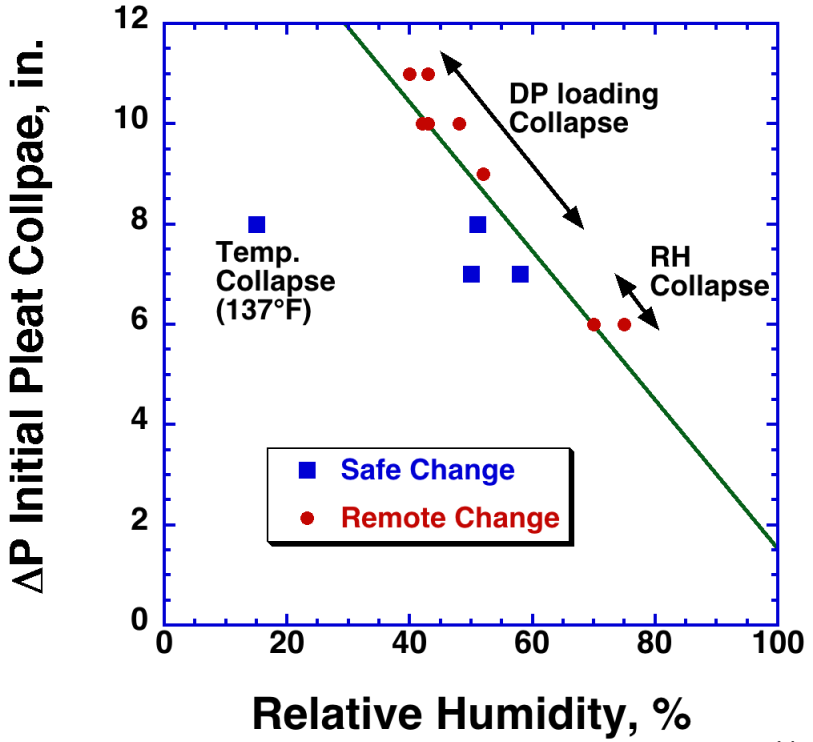


Air flows through fraction of media in collapsed pleats



Pleat collapse at lower DP reduces particle loading.

Pleat collapse induced by increased particle loading at constant RH and T, or by increasing T or RH at constant particle loading.



Background

- Previous filter qualification testing was performed by Mississippi State University to determine performance of a radial flow HEPA filter designs.
- This filter was exposed to loading combined with coincident high temperature and high relative humidity.

Background

- After approximately 30 minutes under combined conditions (4 inches WC loading, approximately 130°F and 50% relative humidity) the test filter differential pressure (DP) increased dramatically and the particle loading capacity was dramatically reduced. Both of these consequences were due to pleat collapse.

- Thirty minutes would not allow time for credited operator response to protect the HEPA filters and prevent failure.

- Filter loading conditions that exceed the structural strength of a currently available ASME AG-1 radial flow HEPA filter can prevail under WTP accident conditions.

Design Considerations

- In addition to requirements of ASME AG-1; the bounding parameters for normal, off-normal, and accident conditions that govern WTP HEPA filter design criteria consist of:
  - Temperature
  - Relative Humidity (RH)
  - Differential Pressure
  - Particle Loading Capacity
- Maintaining the functional integrity of WTP filtration systems requires countermeasures to protect the filter medium from unacceptable degradations in performance.

Design Considerations

- To achieve the required functional design integrity of WTP HEPA filters, the following two options were considered:
  - Option 1: Improve the intrinsic strength of the HEPA filter (e.g., by modifying the filter medium, adding pleat separators, etc.).
  - Option 2: Alter the process conditions upstream of the filters, or add equipment so that the HEPA filter can operate satisfactorily in modified conditions.

Design Considerations

- Option 1: Improve the intrinsic strength of the WTP HEPA filter design.
  - This approach is being used by the WTP and will require modifications to the current WTP HEPA filter design.
  - This approach was previously considered in the early 1990's with metal media HEPA filters being proposed for use at the Hanford Vitrification Plant.
  - Advantages of more robust, high strength filters include:
    - Enhanced reliability for confinement
    - Reduced cost for safety features needed to protect filters
    - Allows optimization of plant processes decoupled from exhaust concerns
  - Disadvantages of high strength filters include:
    - higher cost
    - higher clean pressure drop
    - slightly lower particle loading capacity

Design Considerations

- Option 2: Alter the process conditions upstream of the filters, or add equipment so that the HEPA filter can operate satisfactorily in modified conditions.
  - This approach relies on the expectation that each process will be designed with sufficient features (e.g., heaters, air treatment systems, etc.) to sufficiently mitigate such conditions at their source to minimize degradation of the HEPA filters located downstream.
  - Altering upstream process conditions or adding upstream devices would result in significant cost increases, and have the potential risk of failure.

Design Considerations

- Once it has been determined to use high strength HEPA filters, then: How do you qualify the filter?
- HEPA filters using glass-fiber filter medium are qualified to be of nuclear grade in the U.S. according to ASME AG-1, Section FC (HEPA Filters), and Section FK (Special HEPA Filters).
- These two code sections serve to specify the minimum performance levels of what can be referred to as conventional filter designs (i.e., those which incorporate a filter medium of glass fiber without any strength reinforcement).

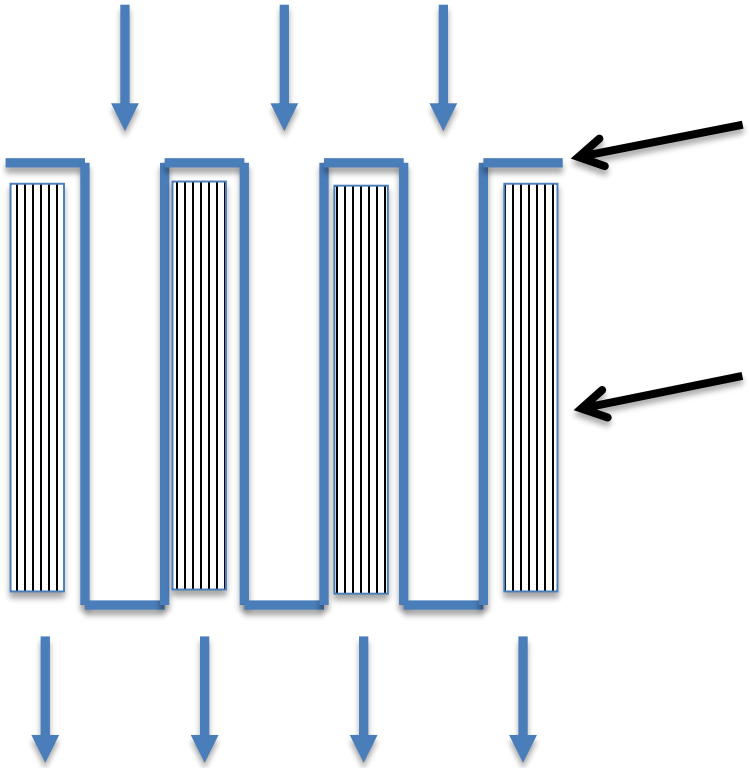
Design Considerations

- Although high strength nuclear-grade HEPA filters have been available in Europe for more than 20 years, their use in select, critical applications within the U.S. has been precluded by the lack of code-based test standards, which are prerequisites to their qualification and implementation in practice.

- Most doubts about filter reliability in-service could be addressed by high strength HEPA filters. Given the commercial availability of high strength HEPA filters within the U.S. and current knowledge of the challenges posed to conventional filters; high strength HEPA filters should be developed with associated qualification test requirements.

Design Considerations

- High strength filter produced by two filter design changes:

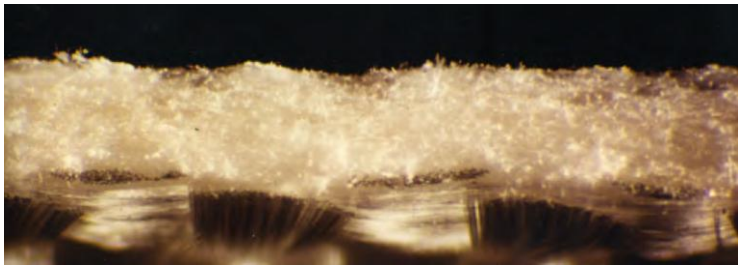


(1) Add support layer to medium

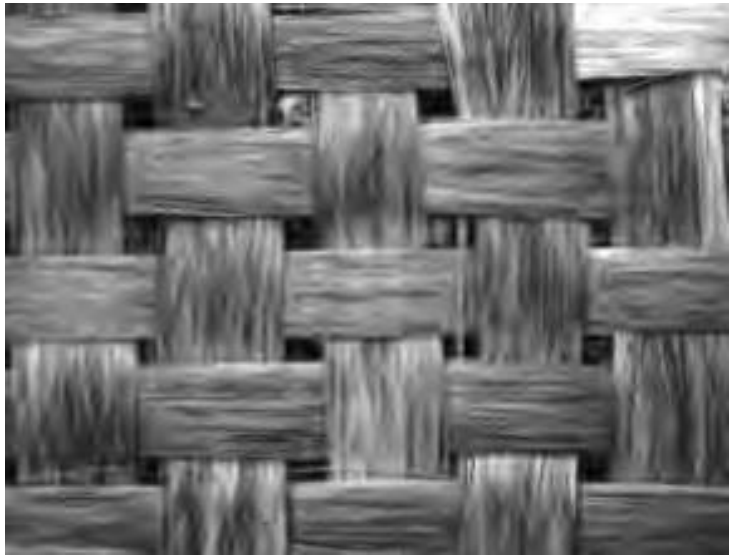
(2) Add separator to downstream pleats

Design Considerations

- Support layer greatly increases tensile strength of glass fiber medium.



Glass fiber medium



Glass cloth support

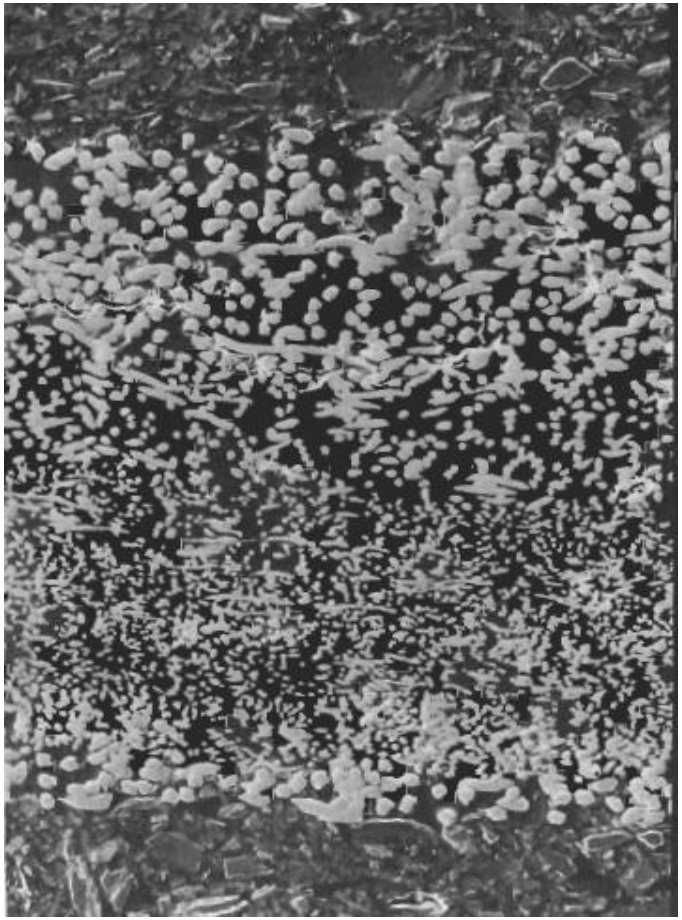
Design Considerations

- Support layers greatly increase tensile strength of steel fiber medium.

Coarse fiber support →

Steel fiber medium
(Tensile strength comparable to glass fiber) →

Coarse fiber support →



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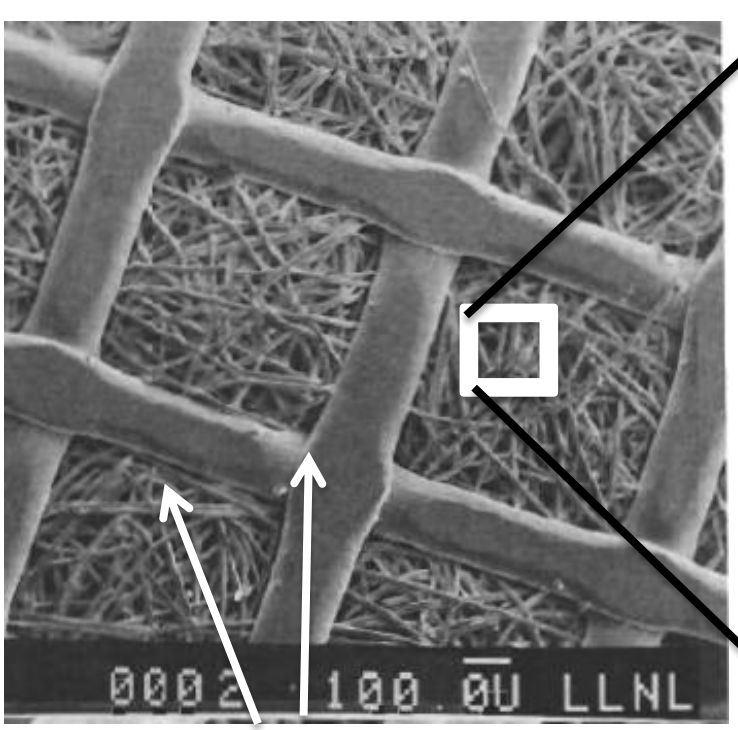
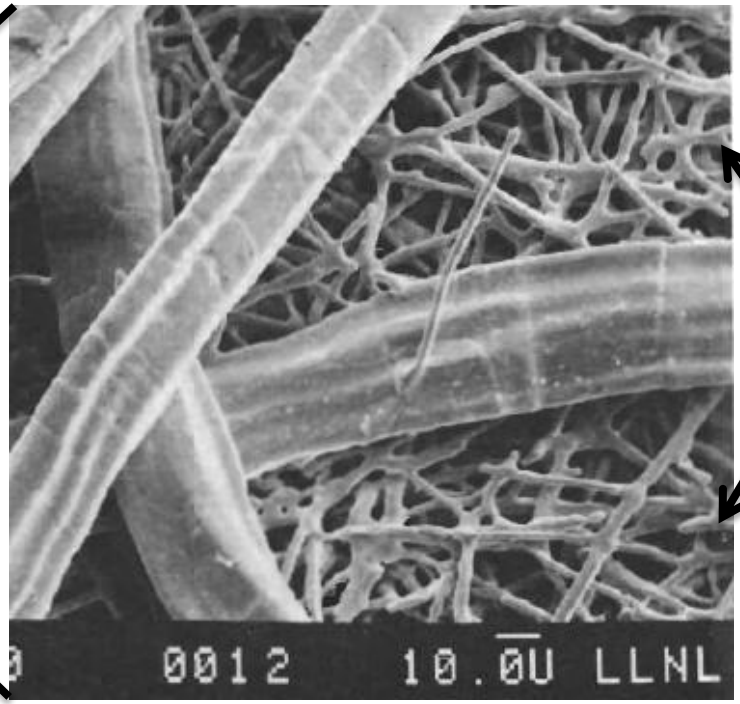
Design Considerations

- Some steel fiber manufacturers have several layers of medium support



Support layers



Fiber Medium

Magnification reveals fiber medium below support layers

Path Forward

- The WTP has created a HEPA filter specification and a HEPA filter test specification to develop high strength HEPA filters.
- The HEPA filter specification cites ASME AG-1 and allows the following three media types:
  - Fiberglass
  - Reinforced Fiberglass
  - Metal fiber

Path Forward

- The HEPA Filter Test Specification requires testing in two phases.
- Phase 1 testing includes three opportunities as needed for design modifications to demonstrate that prototype HEPA filters meet WTP design requirements prior to Phase 2 testing, in which no design modifications are allowed.
- The Phase 1 testing is largely a structural test that allows for early determination of pleat collapse or filter burst under significant differential pressure conditions.
- Phase 1 testing will require a testing infrastructure that use a high viscosity test liquid to qualify filters to 225 inches WC.

Path Forward

- Phase 2 testing will:
  - Characterize and qualify the performance of the HEPA filters selected from the Phase 1 testing process, and
  - Support the selection of the representative designs for the WTP HEPA filters with their maximum differential pressure rating that will be installed in the WTP ventilation and off-gas exhaust systems.

Status

- The major change is the development of an alternative to the ASME AG-1 resistance to pressure test.
- MSU is developing a Resistance to Liquid Pressure Test Stand (RLPTS) using a high viscosity liquid for testing WTP filters to 225 inches WC.
- Initial testing with the MSU RLPTS has shown that this concept, using liquid, is an acceptable method of testing filters to 225 inches WC.

Status

- The resistance to liquid tester has been successfully demonstrated at Mississippi State University (MSU) under the direction of Dr. Charles Waggoner.

- The next presentation will discuss, “Development of a Resistance to Liquid Pressure Test System (RLPTS) for Qualifying HEPA Filters.”

Questions?