Waste Treatment Plant Project

Development of a Resistance to Liquid Pressure Test System (RLPTS) for Qualifying HEPA Filters

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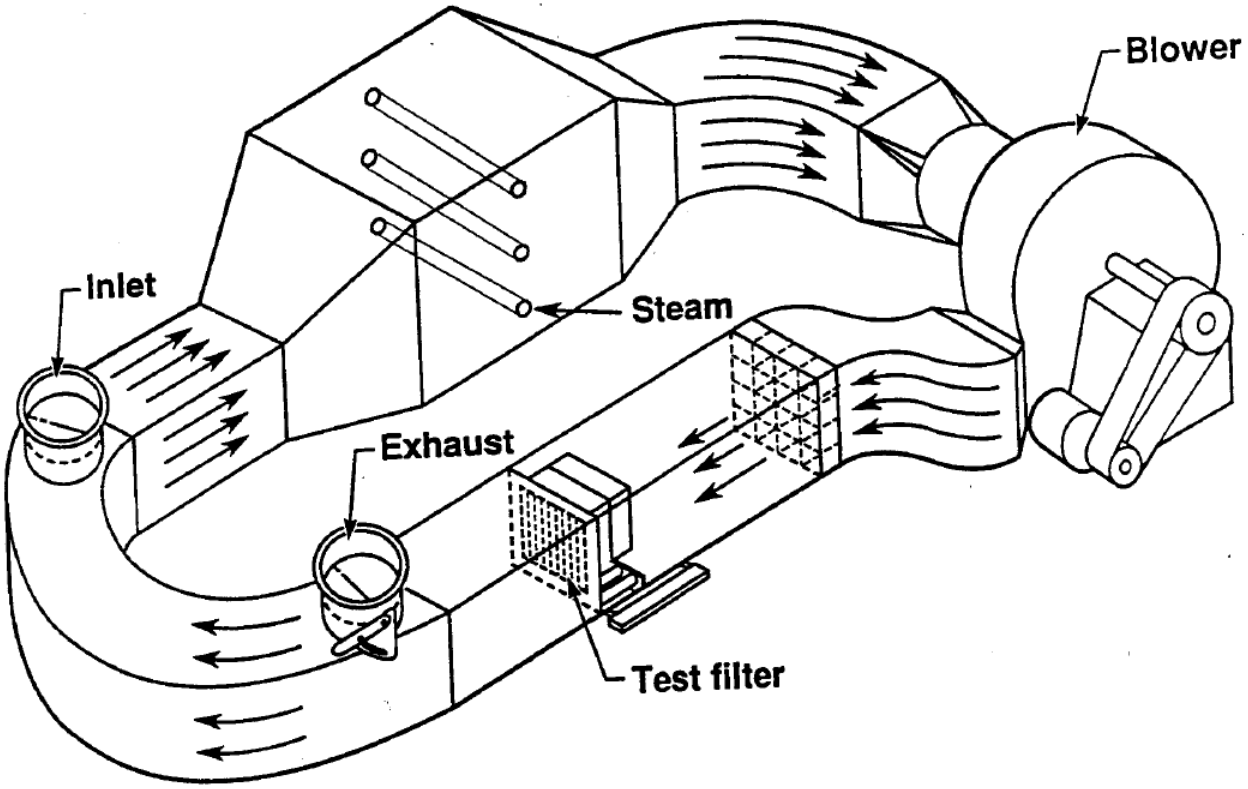
Introduction

- AG-1 HEPA filters must be tested for resistance to 10 inches WC differential pressure (DP) in moist, warm air for 60 minutes



Introduction

- Current ASME AG-1 test requirements are not sufficient for qualifying HEPA filters for use at

- WTP needs a method for qualifying filters up to 225 inches WC

Approach

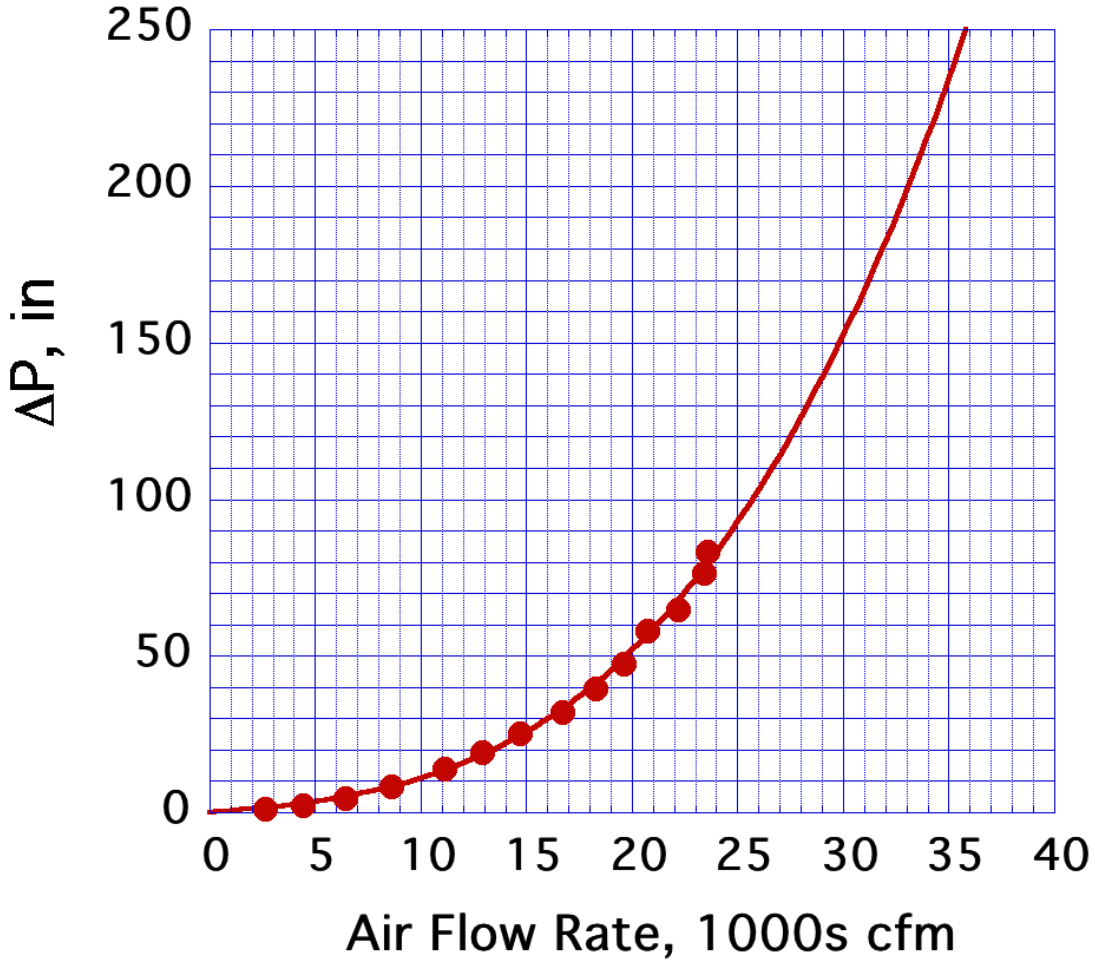
- Pressure flow equation provides two methods for increasing filter pressure drop:

(1) Increase the flow rate

$$\mathrm{D}P = k\,h\,V$$

(2) Increase the fluid viscosity

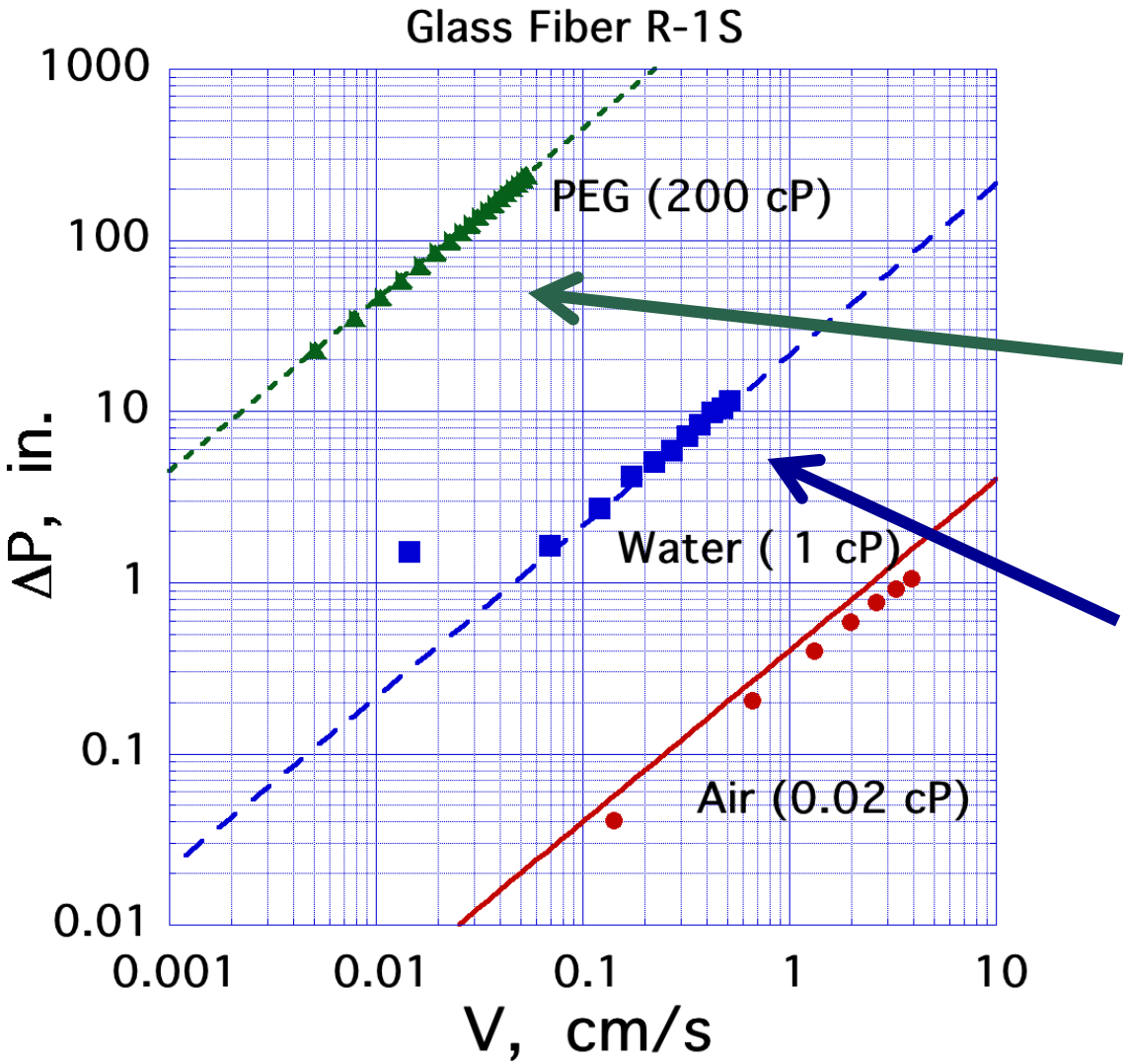
Approach



HEPA flow data from tornado simulations Gregory et al, 1978

- Qualifying WTP filters with air presents challenges
- Expensive and not practical

Approach

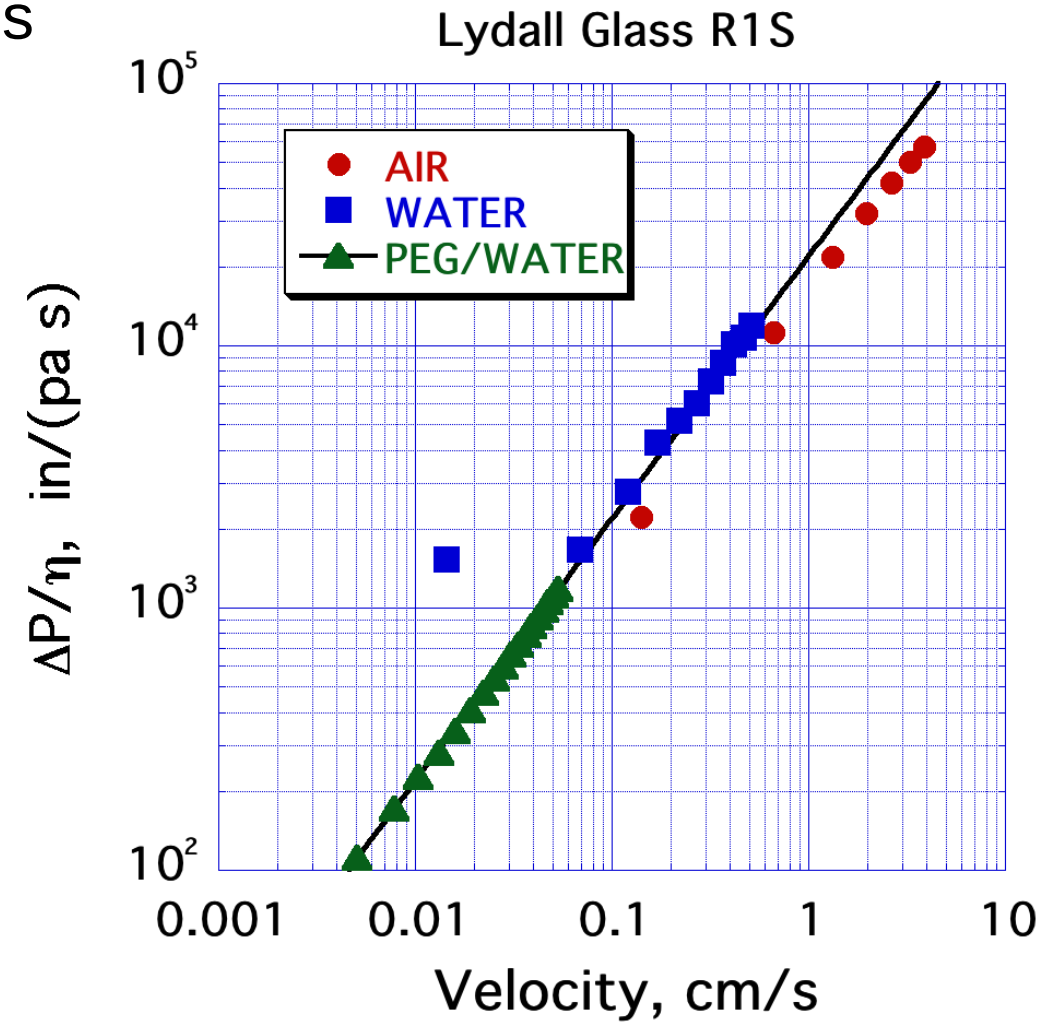


- Pressure increases directly with viscosity
- High viscosity fluid can produce high pressure at low flows
- Water alone is not enough

Approach

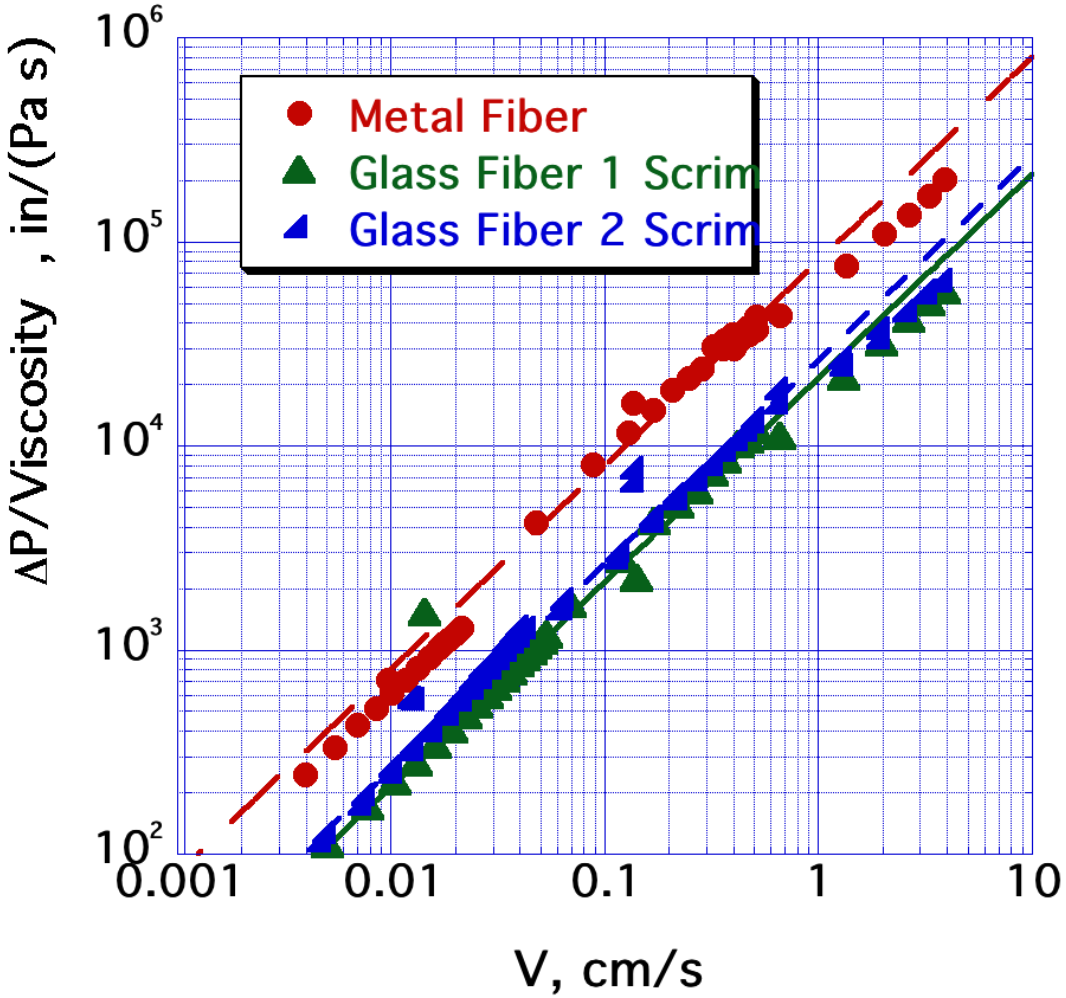
- Validated the pressure flow equation for various fluids and confirmed assumptions

$$\frac{DP}{h} = kV$$



Approach

- Validated pressure flow equation for various media types

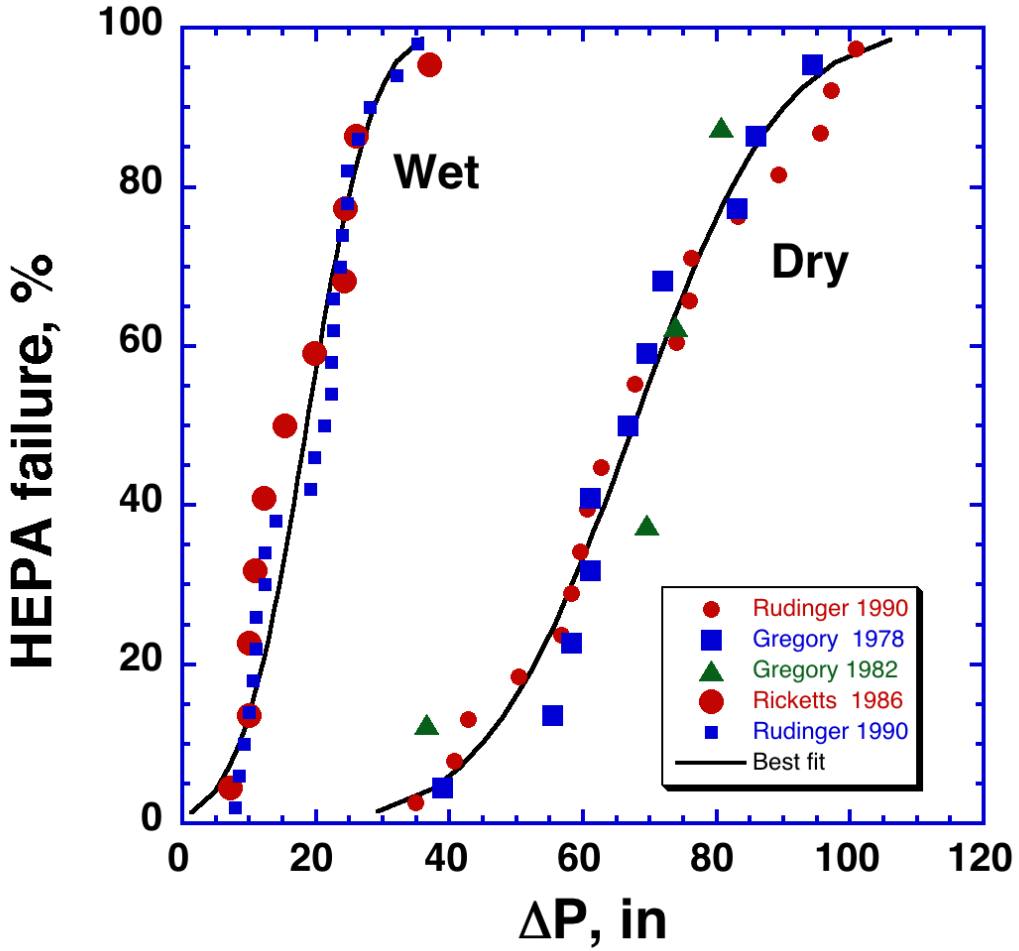


$$\frac{\mathrm{D}P}{h} = kV$$

Motivation for Developing Resistance To Pressure Qualification

- **ASME AG-1** filter qualification is limited to:
  - 10 inches WC
  - 95% RH ± 5%
  - 95°F ± 5°F
- **WTP** high strength HEPA filters must withstand:
  - 225 inches WC
  - 95% RH ± 5%
  - 170°F ± 5°F
- Moisture and elevated temperature used to expose filter to realistic process conditions

Motivation for Developing Resistance To Pressure Qualification



- Consistent with ASME AG-1
- Moisture and elevated temperature weaken filter

Motivation for Developing Resistance To Pressure Qualification

- Determined current approach using *air flow* not feasible
  - Volume of air flow needed is unrealistically high
  - Would require very large fan or pressure blower
  - Significant hardware and infrastructure costs

- New approach needed to develop a resistance to pressure test capable of 225 inches WC

Motivation for Developing Resistance To Pressure Qualification

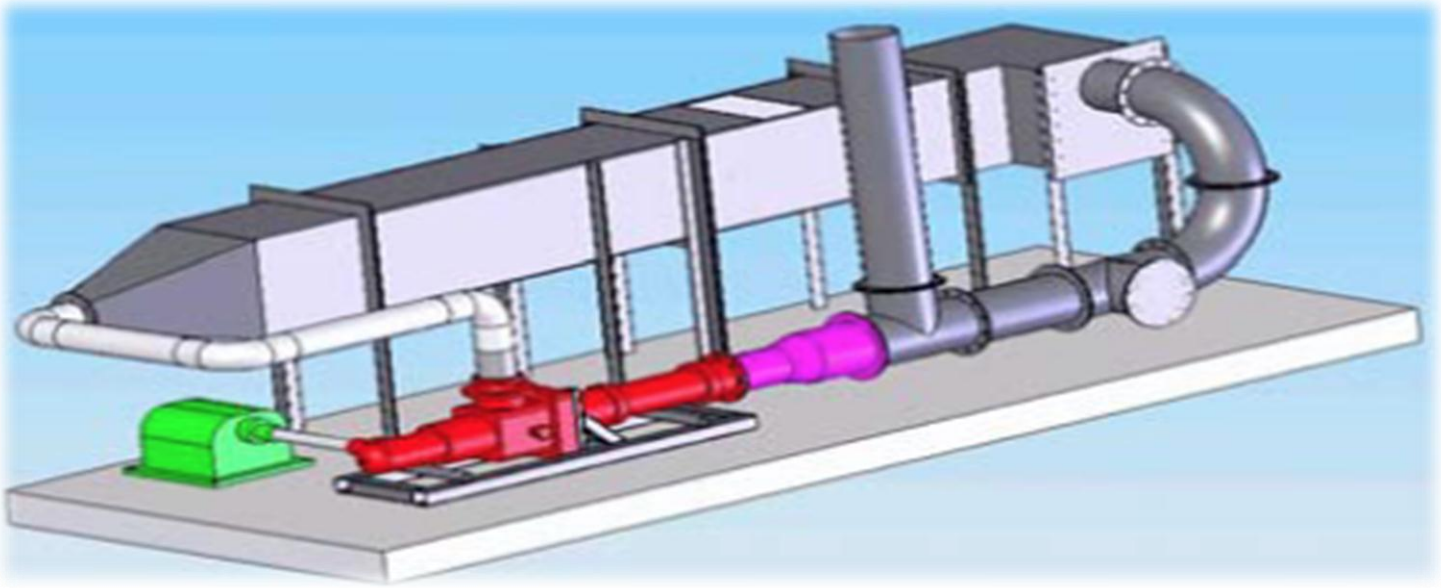
- Since HEPA filter pressure drop is directly proportional to fluid flow and viscosity, high pressures can be obtained by either a high *flow* or a high *viscosity*
- High *flows* of either gas or liquid require very large and expensive equipment
- Increasing *viscosity* allows for high pressure with low or moderate cost

Motivation for Developing Resistance To Pressure Qualification

- Rationale for developing a liquid DP test apparatus include:
  - Availability of high viscosity liquids
  - Low liquid flow rate
  - Low pump horsepower
  - Small diameter piping requirements
  - Simple application of filter pressure drop fundamentals
  - Practical size and cost considerations
  - Precedent set by industry using ISO Standards for testing hydraulic filters

Previous Work for Developing Resistance To Pressure Qualification

- Ricketts (1998) tested HEPA filters for resistance to pressure with constant water flow
- Only reached 60 inches WC with a 500 gpm pump in a 95°F recirculating water loop
- Viscous additives were not explored



Previous Work for Developing Resistance To Pressure Qualification

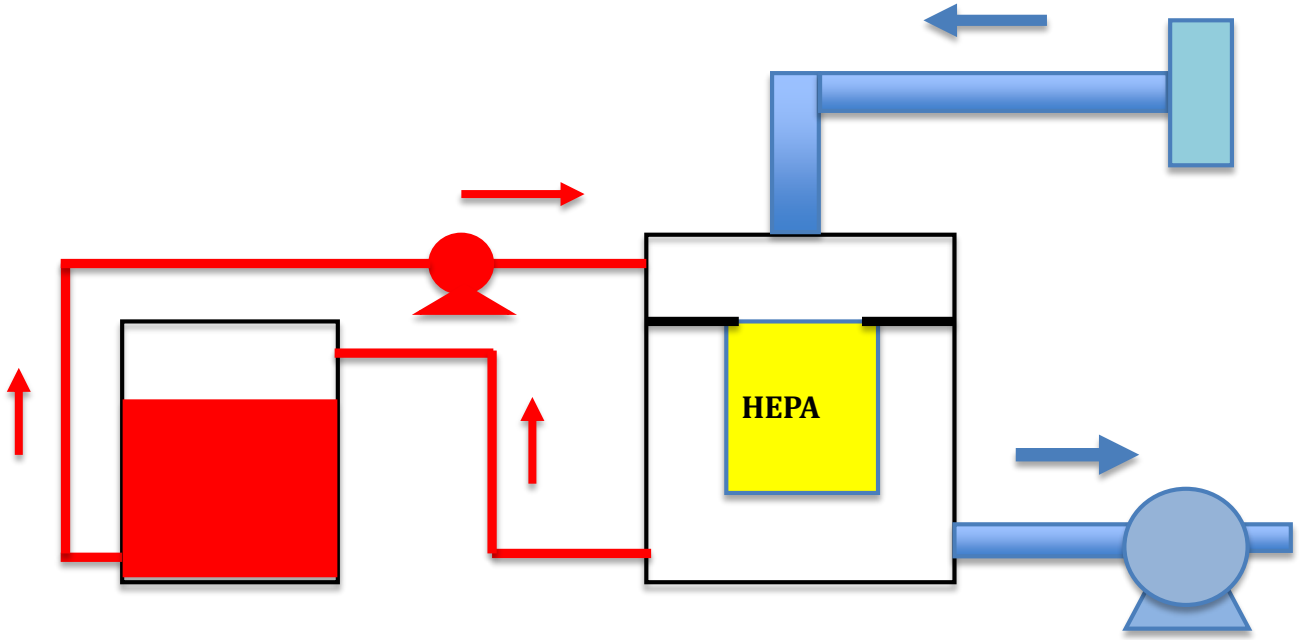
- Ricketts (2008,2010,2012) developed a higher pressure test system using a transient slug of water
- This approach was not considered by the WTP because:
  - Cannot expose the filter for the *required 1 hour*
  - Cannot determine filter failure due to *pleat collapse*
  - A transient pulse is difficult to analyze

RLPTS Design Criteria

- The **RLPTS** was based on the following criteria:
  - Must accommodate WTP filter size and dimensional configuration
  - Must operate under elevated constant temperature
  - Must produce rated constant pressure using high viscosity fluid to obtain high DP with minimal flow
- The **test liquid** selection criteria
  - High viscosity
  - Water soluble to allow rinsing of the filter
  - Non-toxic to minimize waste and disposal challenges
- Test liquid chosen:
  - Polyethylene Glycol (PEG) in water solution

RLPTS Design

- BNI has contracted Mississippi State University (MSU) to develop a Resistance to Liquid Pressure Test System as a replacement for ASME AG-1 resistance to pressure test
- Equipped with liquid test loop for high pressure exposure, and air loop for drying filter and measuring filter efficiency



RLPTS Design

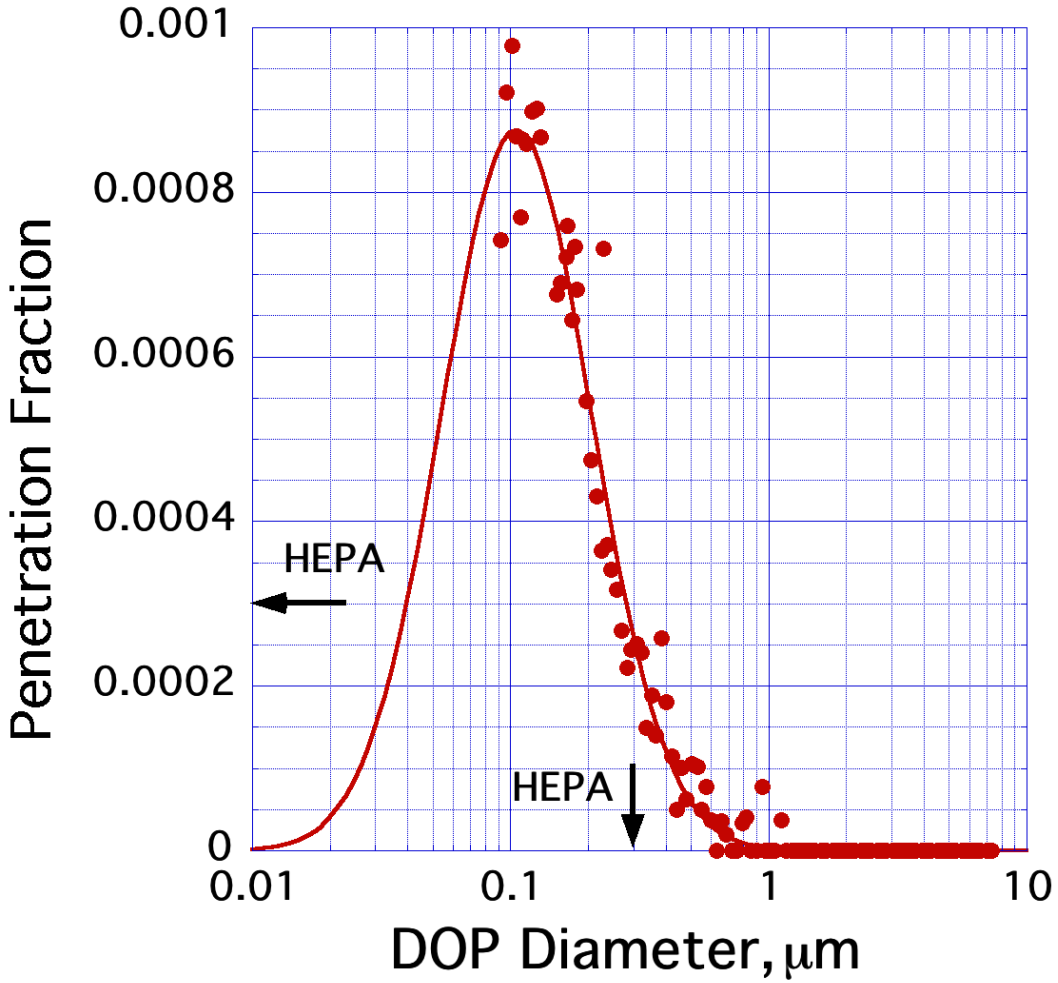
- Modeled after ISO Standards 2941, 3724 and 23181 for testing hydraulic filters
- Similar to ASME AG-1 resistance to pressure test by first exposing filter to the rated pressure for one hour and then testing for DOP aerosol efficiency at 20% rated air flow
- Capable of running rinse water to flush residual PEG that precipitates within filter medium
- Able to assist filter drying by circulating warm air at low flow
- Able to determine filter pleat collapse (not possible with the current AG-1 test)

Failure Mode Analysis

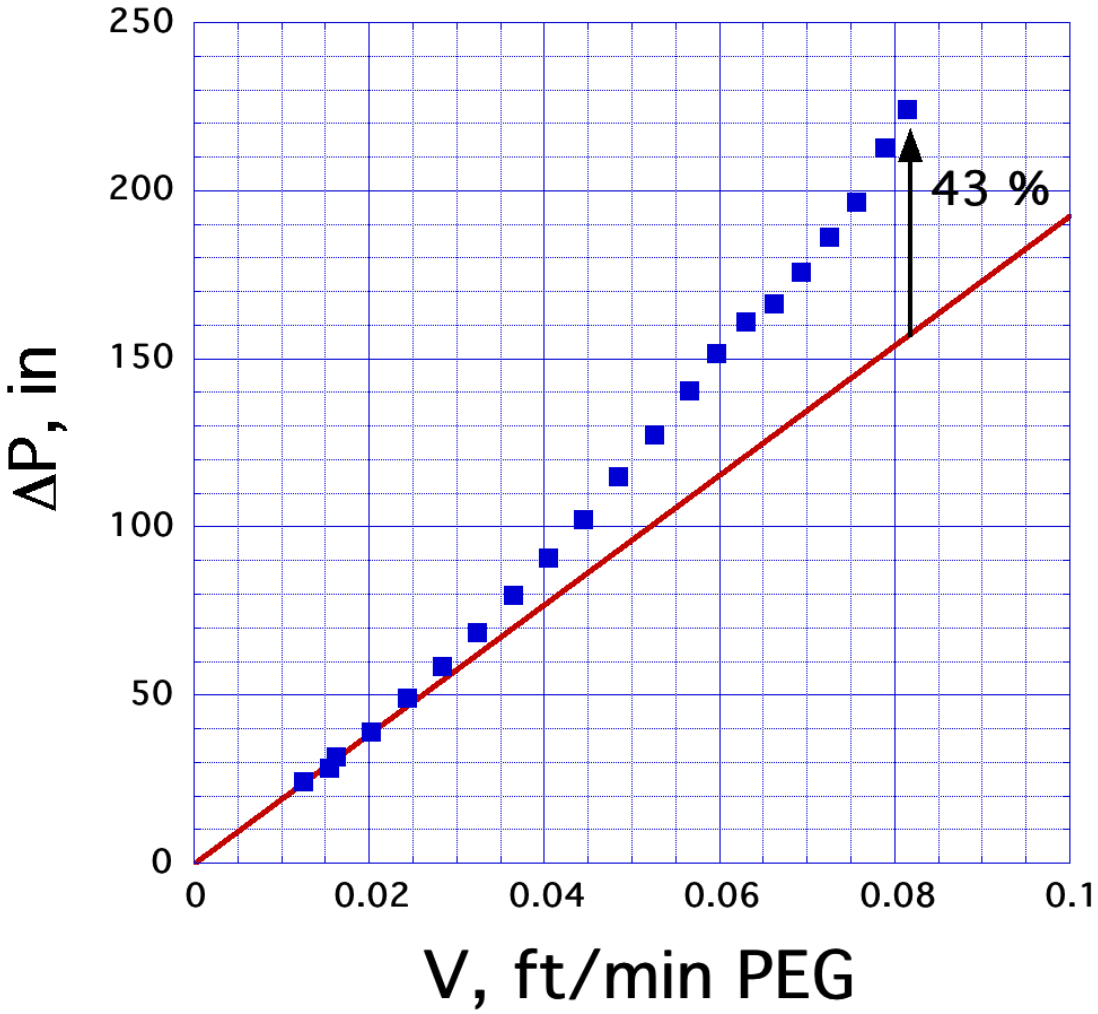
- Pleat collapse is a failure in HEPA filter design because it results in significant increase of flow resistance and adversely affects facility ventilation flow
- Pleat collapse is measured in RLPTS as a highly non-linear filter DP vs flow curve
- Supplemental tests on flat sheet media coupons are used to separate the pressure drop of the media from total pressure drop of the assembled filter

Results

- The filter passed the initial efficiency test.



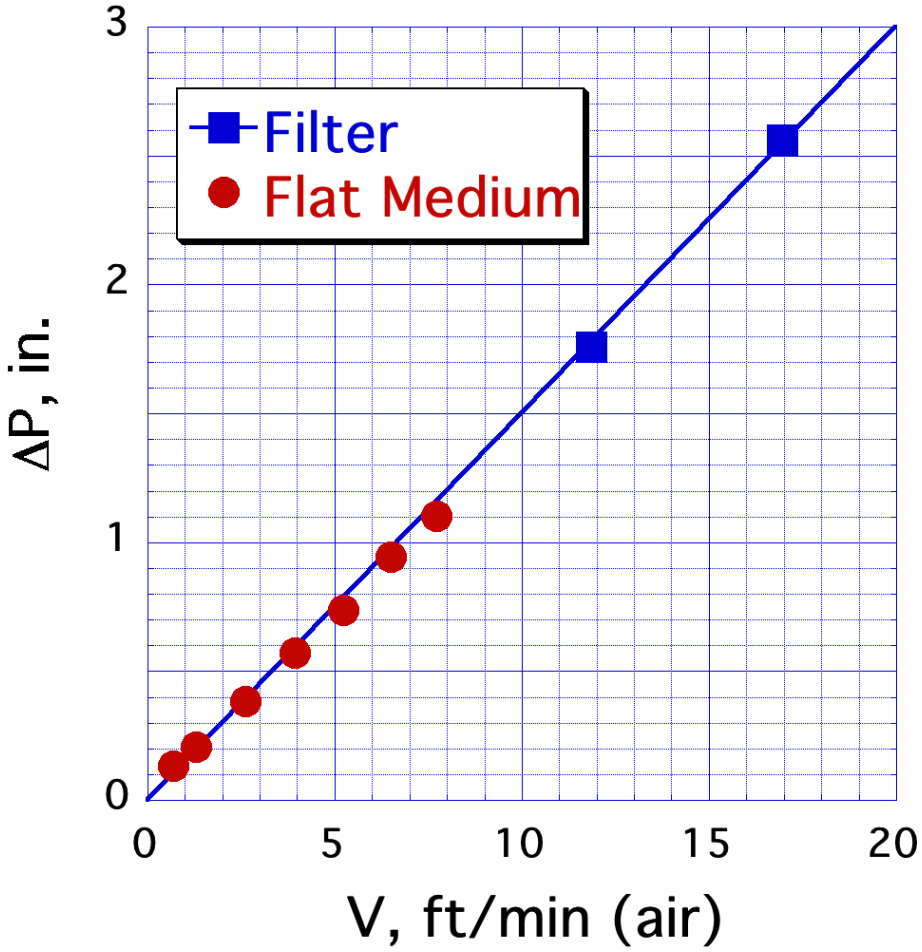
Results



- 43% non-linearity suggests **pleat collapse**
- Test results demonstrate RLPTS performs successfully

Results

- Compare DP vs. flow for flat sheet media coupons & fully assembled filter

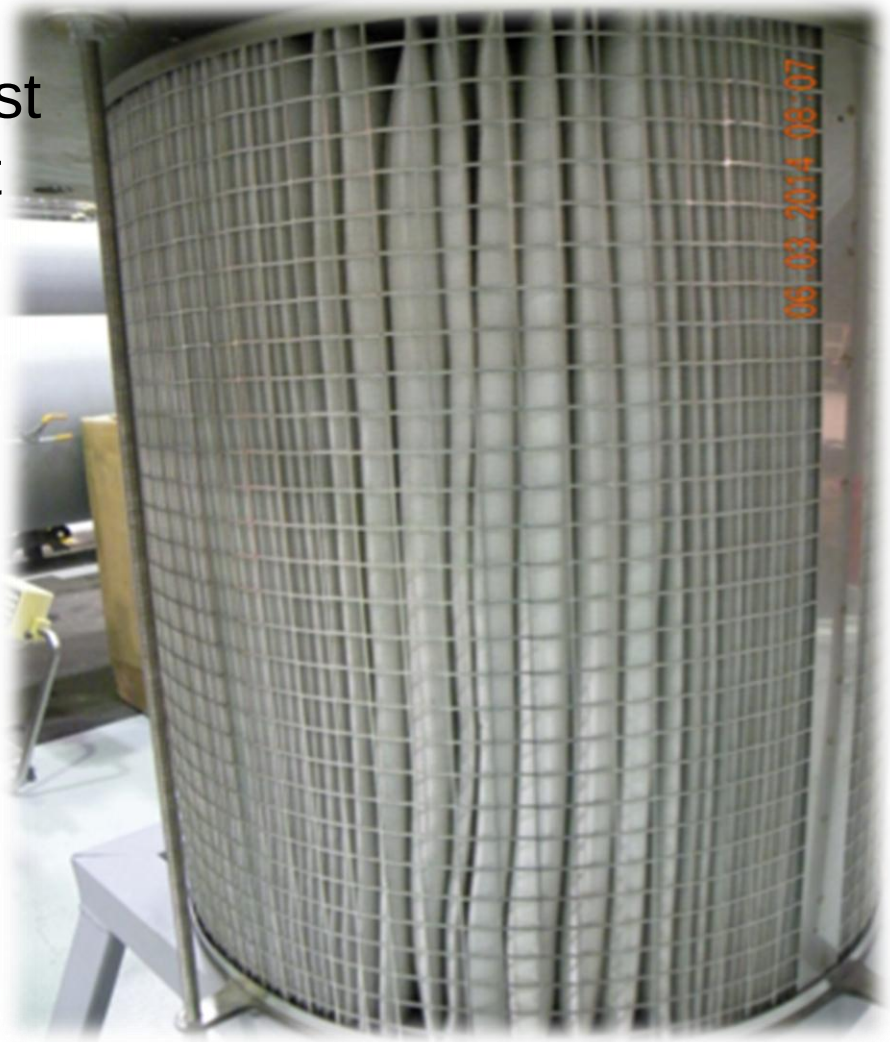


- Lowest DP achievable for assembled filter is equal to DP of media alone
- Pre-test shows filter DP is primarily due to medium (good result)
- Post liquid efficiency test was not run
- Filters with pleat collapse will show higher filter assembly DP than medium DP (poor result)

Results

- Post test examination of test filter shows extensive pleat ballooning/collapse

- Post test penetration measurement was not successful



Conclusion

- MSU has conducted preliminary full scale HEPA filter qualification tests up to 225 inches WC
- Optimization studies are needed for filter rinsing and drying
- The RLPTS is being used to qualify high strength radial flow HEPA filters for use at WTP

Questions?