Lifecycle Evaluation of Radial Flow HEPA Filters Under Upset Conditions

Work Conducted by the ICET Filter Testing Group

Reported by

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Radial Flow HEPA Filters

- European Experience with Radial Flow Filters
- New Standard (2008), AG-1 Section FK Radial Flow Filters
- Absence of Qualified Filters
- Existing Data
  - Dated (1990)
  - Limited Particle Size Distribution
  - Limited Characterization
- DOE 1066 Fire Protection Guidance

Project Test Plan Development

- ORP Personnel
- DOE-HQ Personnel
- Hanford-RL Personnel
- Bechtel Personnel
- Dr. Vern Bergman
- Sharon Steele, NNSA
- Carter Shuffler, DNFSB
- ATI-FTF Personnel
- Flanders Personnel

Testing of Unqualified Filters

- Remote Change Filters Deemed Most Sensitive to Failure During Upset Conditions
- Filter Pack Parameters

	Remote Change	Safe Change
# of Pleats	330	345
Media (ft^2)	314	320
ID (in)	12.625	13.625

- Wet Overpressure Testing
- ATI FTF Testing

Remote Change FK Filters

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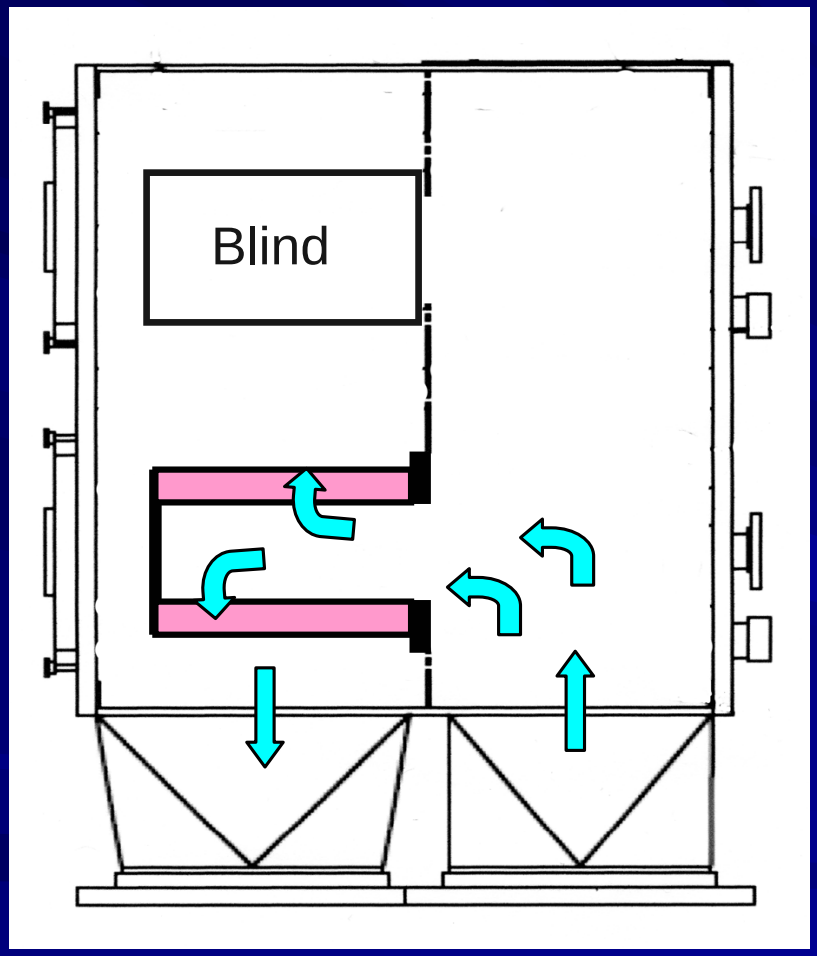
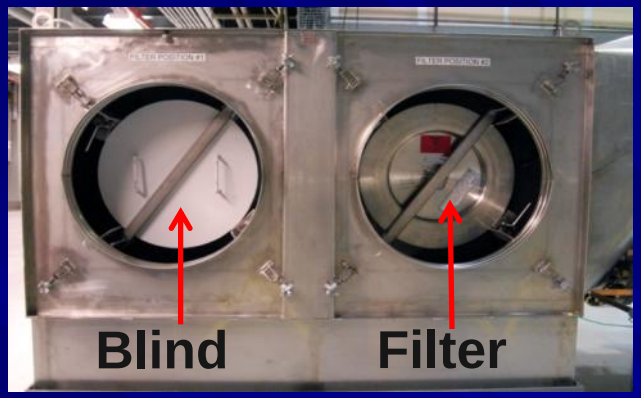
Filter Housing

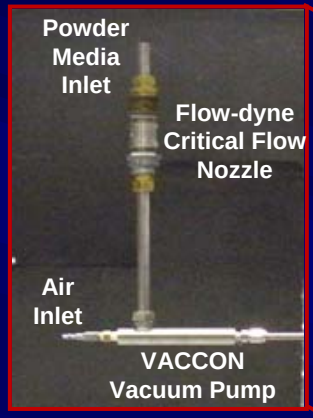
- Modified to Accept Either Safe Change or Remote Change FK Filters
- Houses One or Two Filters
- Sampling Ports
  - Aerosol Measurement
  - Velocity

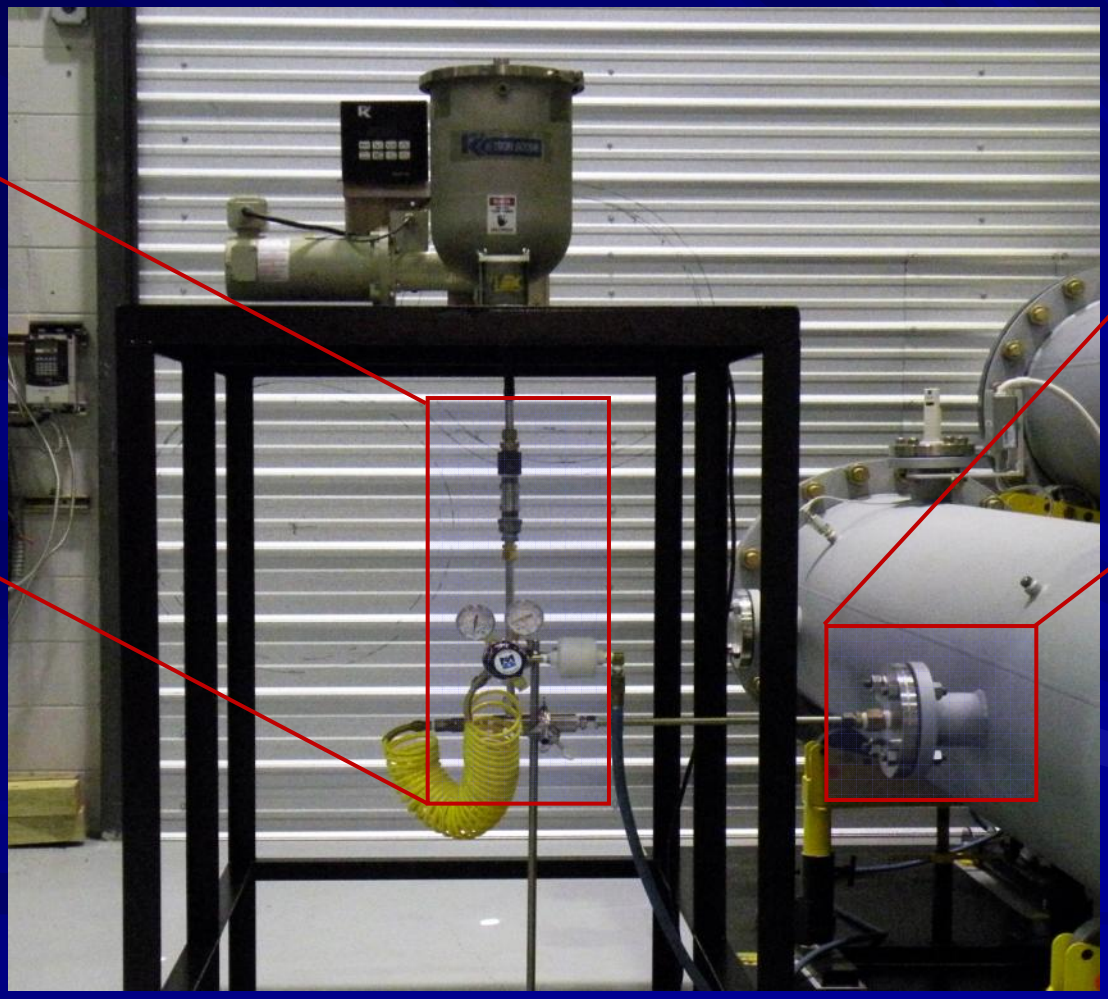
Single FK Radial Filter Airflow During Testing

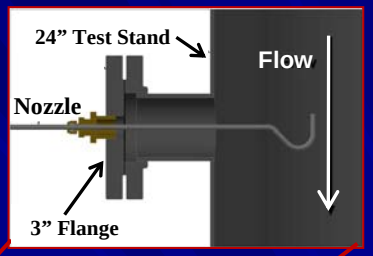




Aerosol Injection

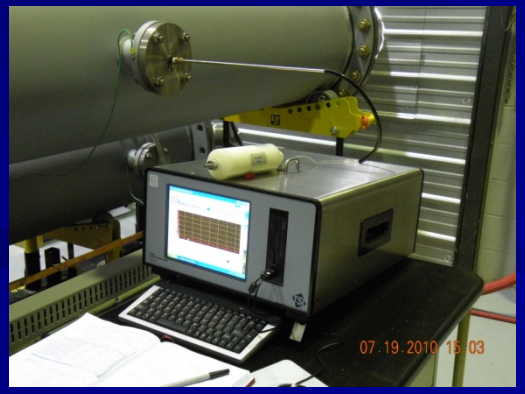


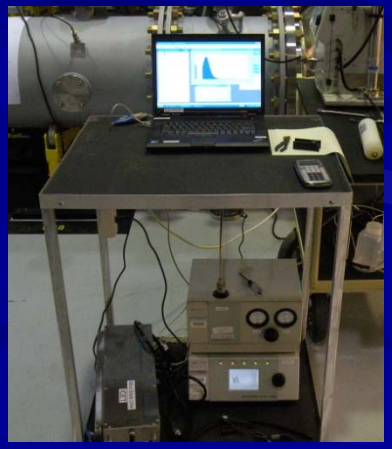




Aerosol Measurement Instruments

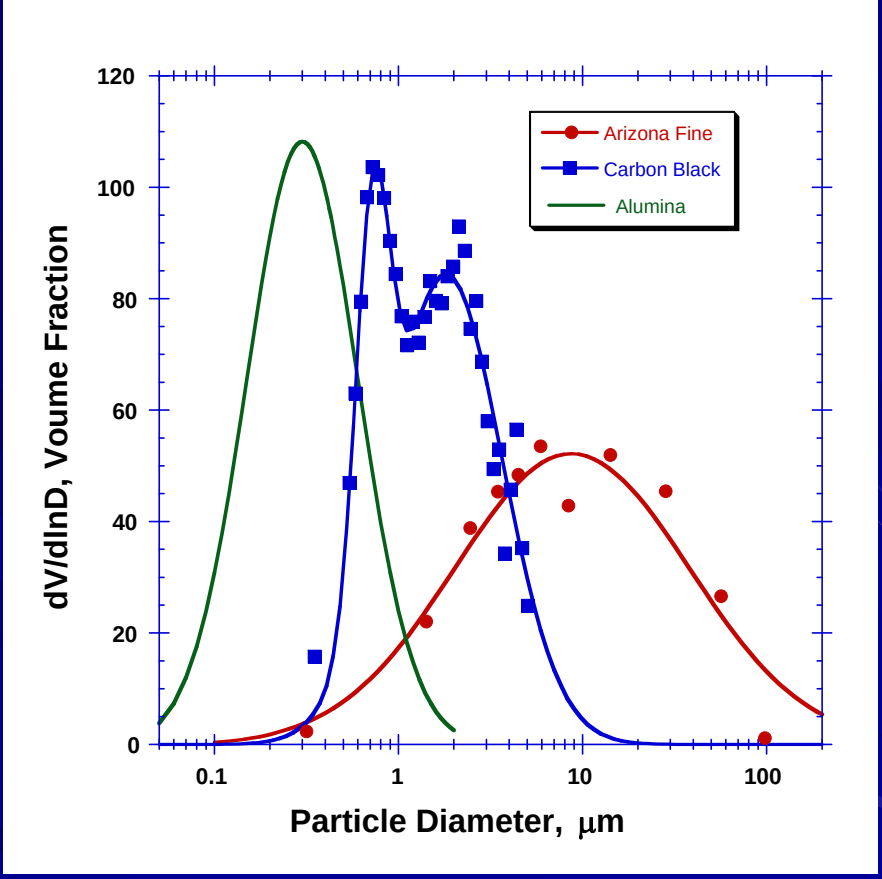
- Upstream
  - TSI SMPS
  - TSI APS
- Downstream
  - TSI Laser Aerosol Spectrometer
  - ATI Aerosol Photometer



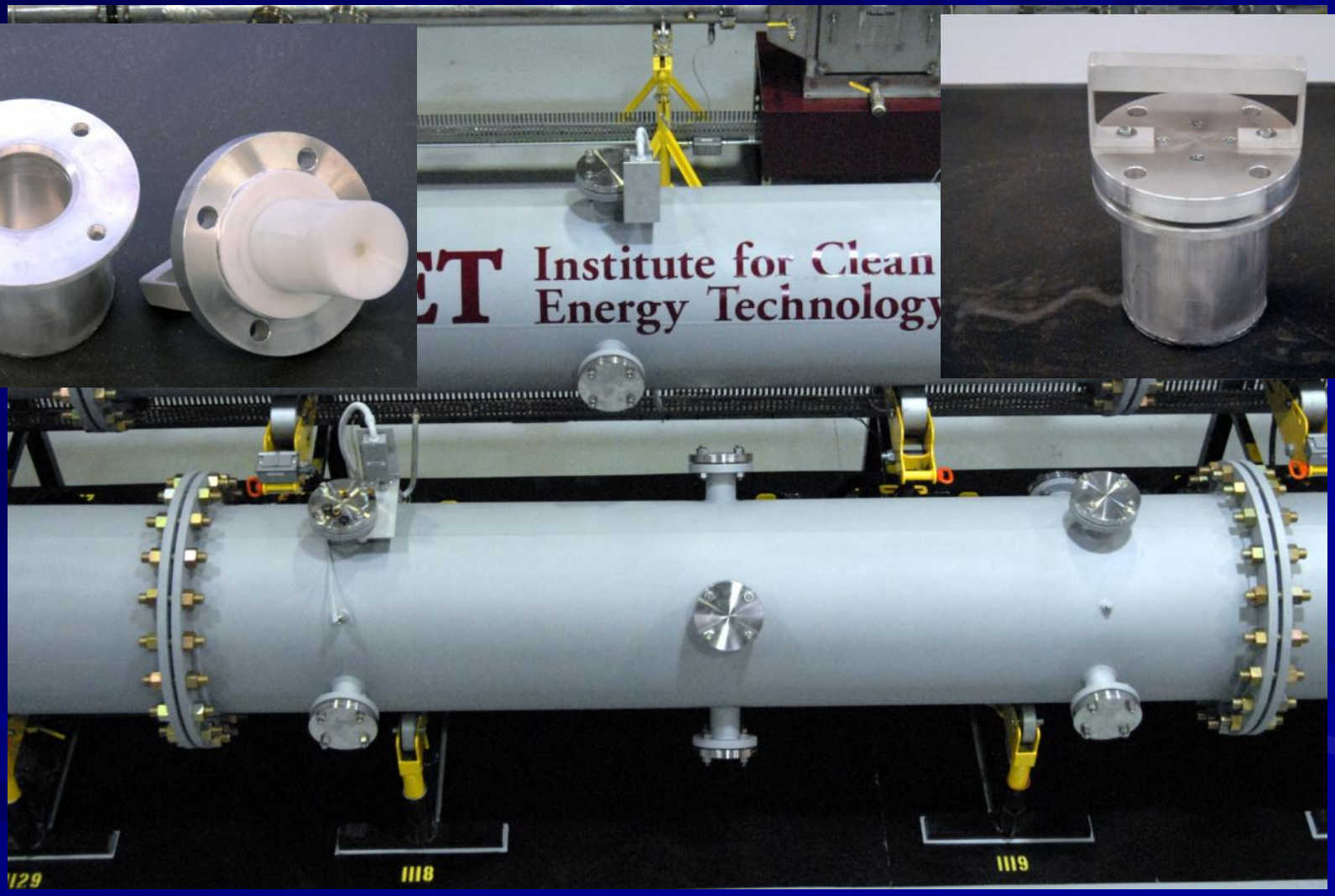


Aerosol Challenge Agents Literature Values of PSDs

- Alumina- $Al(OH)_3$
  - MMD 0.3 µm
  - Used in previous studies on filter clogging
  - Represents loading by small
  - particles
- Carbon Black
  - MMD 1 – 5 μm
  - Similar to aerosols used in UK
  - studies
  - Represents soot from fires
- Arizona Road Dust
  - MMD 5 µm
  - Represents loading by large particles.



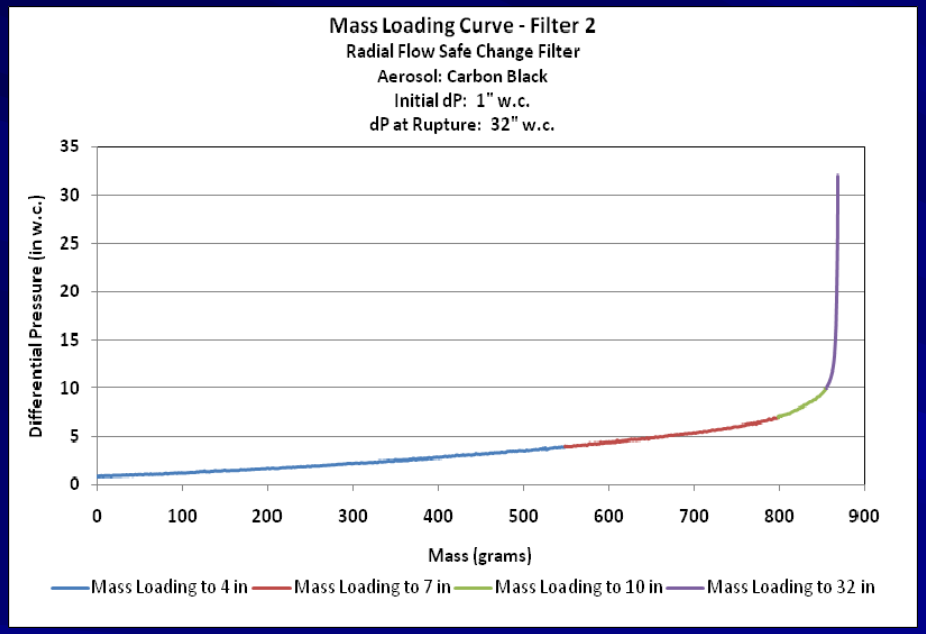
Aerosol Neutralization

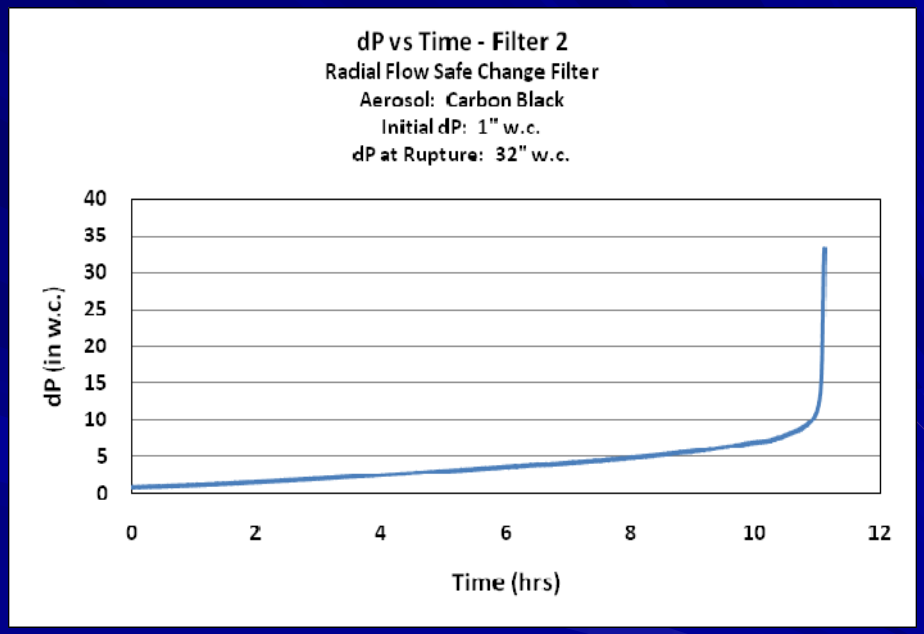


Remote Change Test Matrix

Test Parameters and Guidelines:			Aerosol #1 0.25 µm (Alumina)	Aerosol #2 2.0 µm (Carbon Black)	Aerosol #3 5 µm (AZ Road Dust)
Remote Change HEPA Filter	Data Set 1	Test Set 1: 2000 cfm (56.6 m^3/min) 70-75^{0}F (21.1-23.9^{0}C) 40-50% RH Max dP and/or failure	Filter 1	Filter 2	Filter 3
		Test Set 2: 2000 cfm (56.6 m^3/min) 165-170^{0}F (73.9-76.7^{0}C) 95-100% RH Max dP and/or failure	Filter 4	Filter 5	Filter 6
Remote Change HEPA Filter	Data Set 2	Test Set 1: 2000 cfm (56.6 m^3/min) 70-75^{0}F (21.1-23.9^{0}C) 40-50% RH Max dP and/or failure	Filter 7	Filter 8	Filter 9
		Test Set 2: 2000 cfm (56.6 m^3/min) 165-170^{0}F (73.9-76.7^{0}C) 95-100% RH Max dP and/or failure	Filter 10	Filter 11	Filter 12

Carbon Black Loaded Safe Change

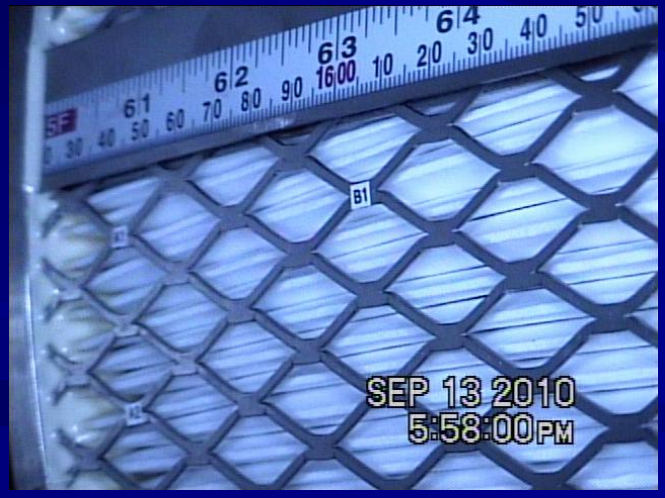




Filter Housing Photos while Loading

3 in dP

10 in dP

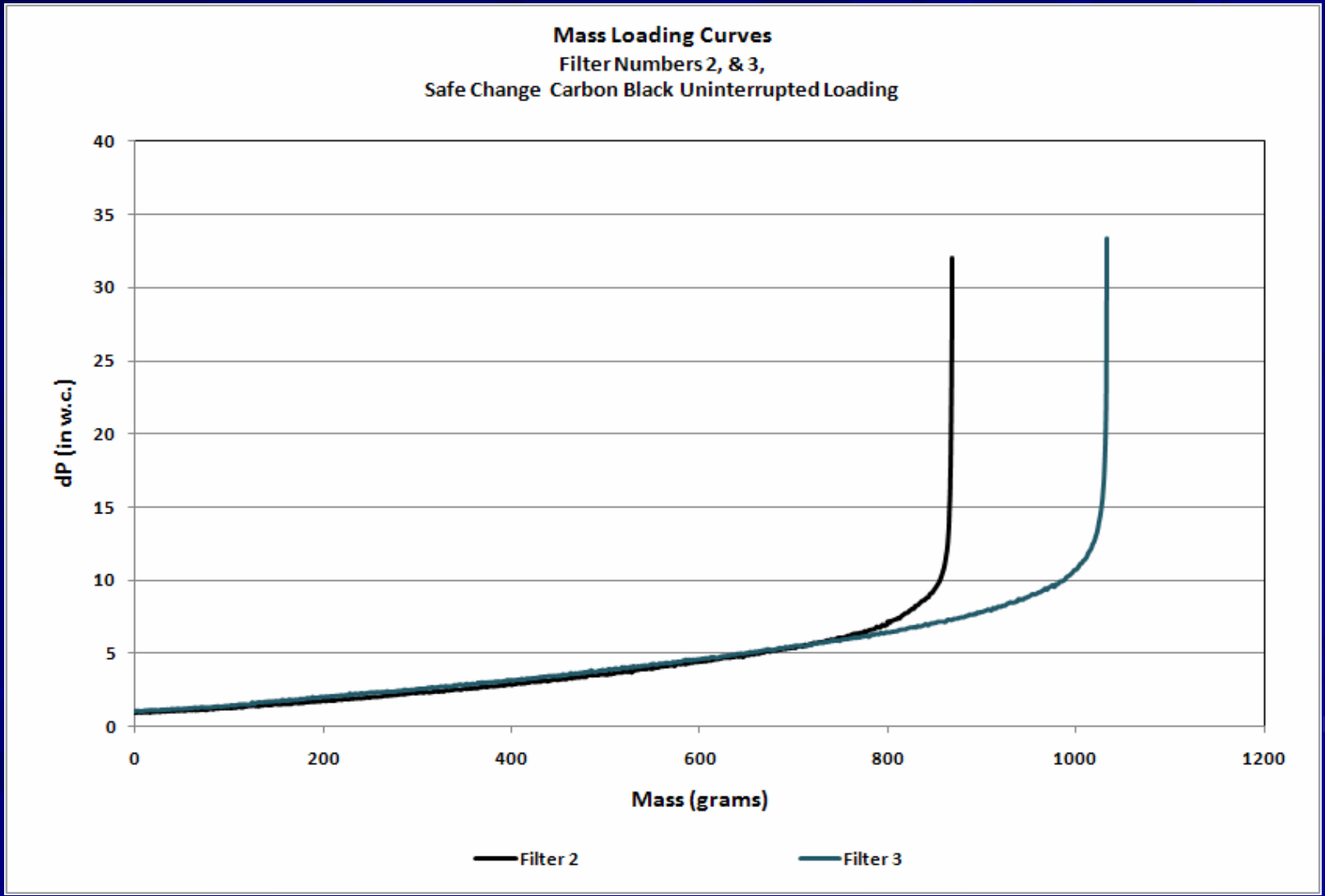


20 in dP

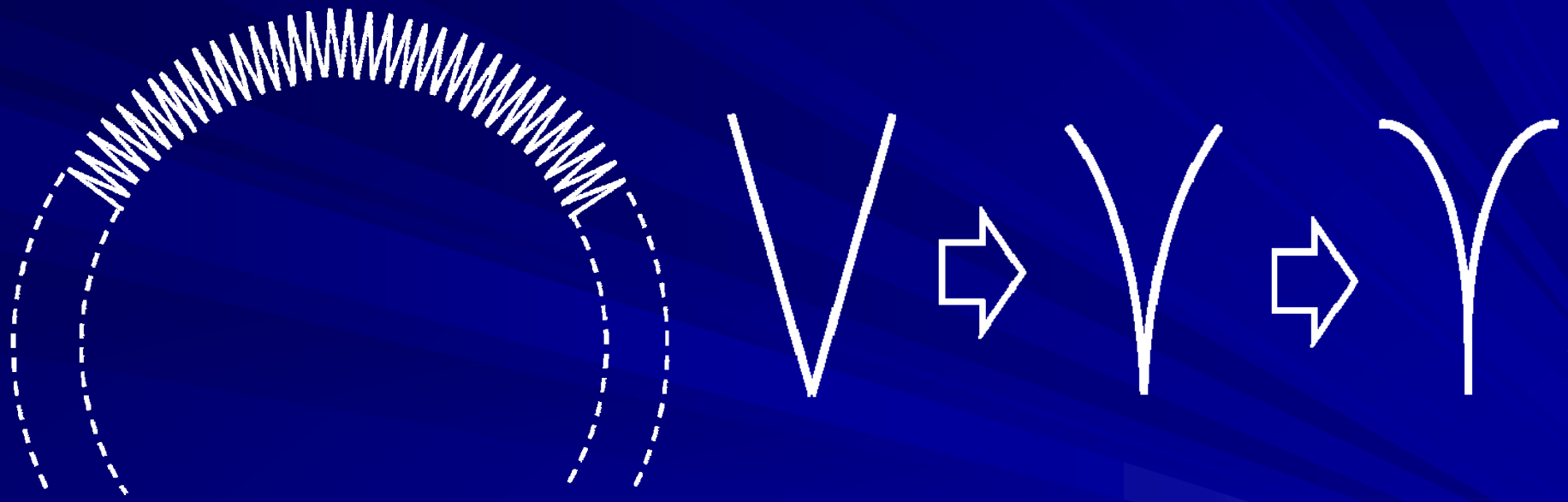
Rupture dP

Ruptured Safe Change Filter

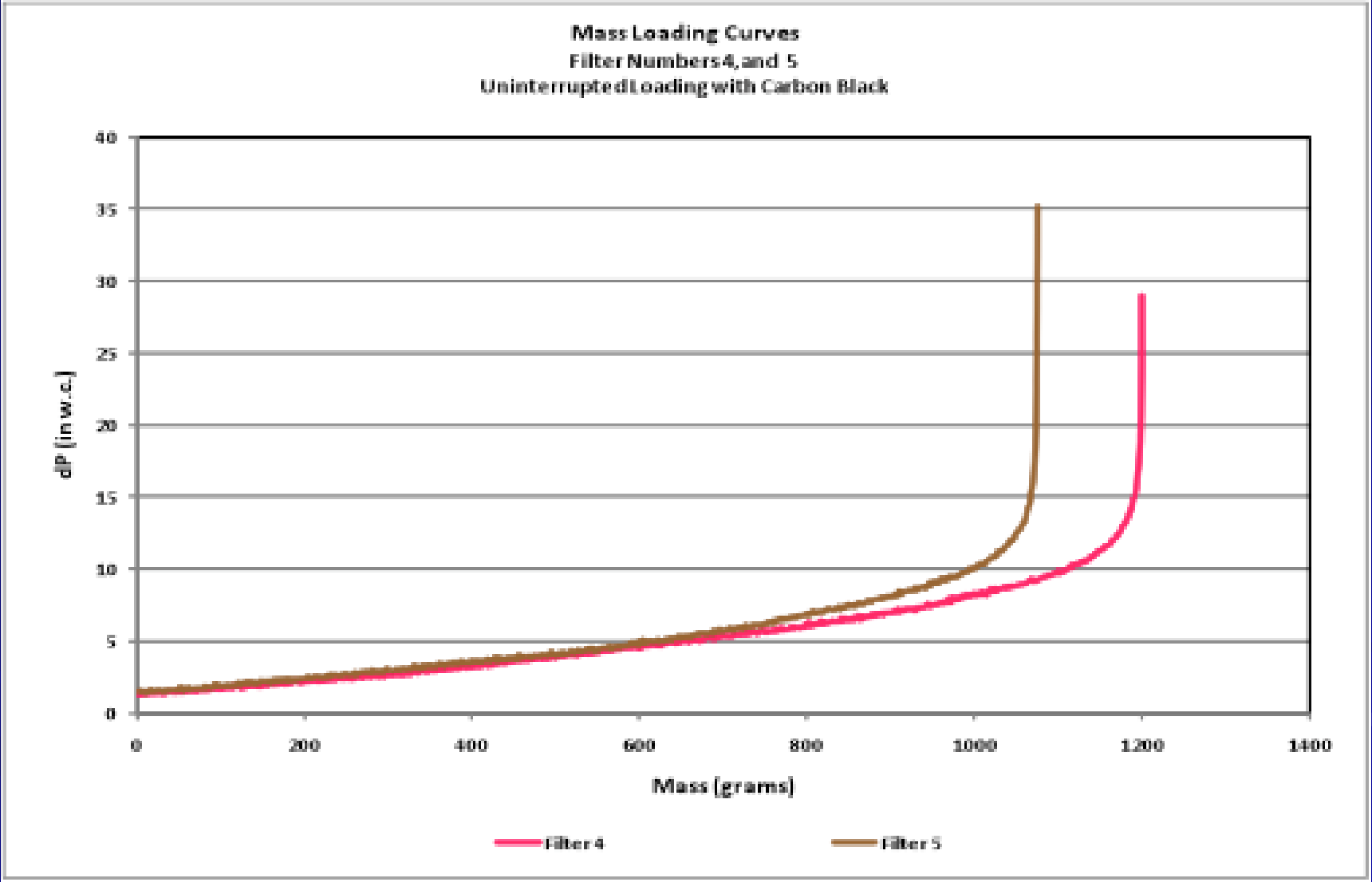
CB Loaded Safe Change Filters



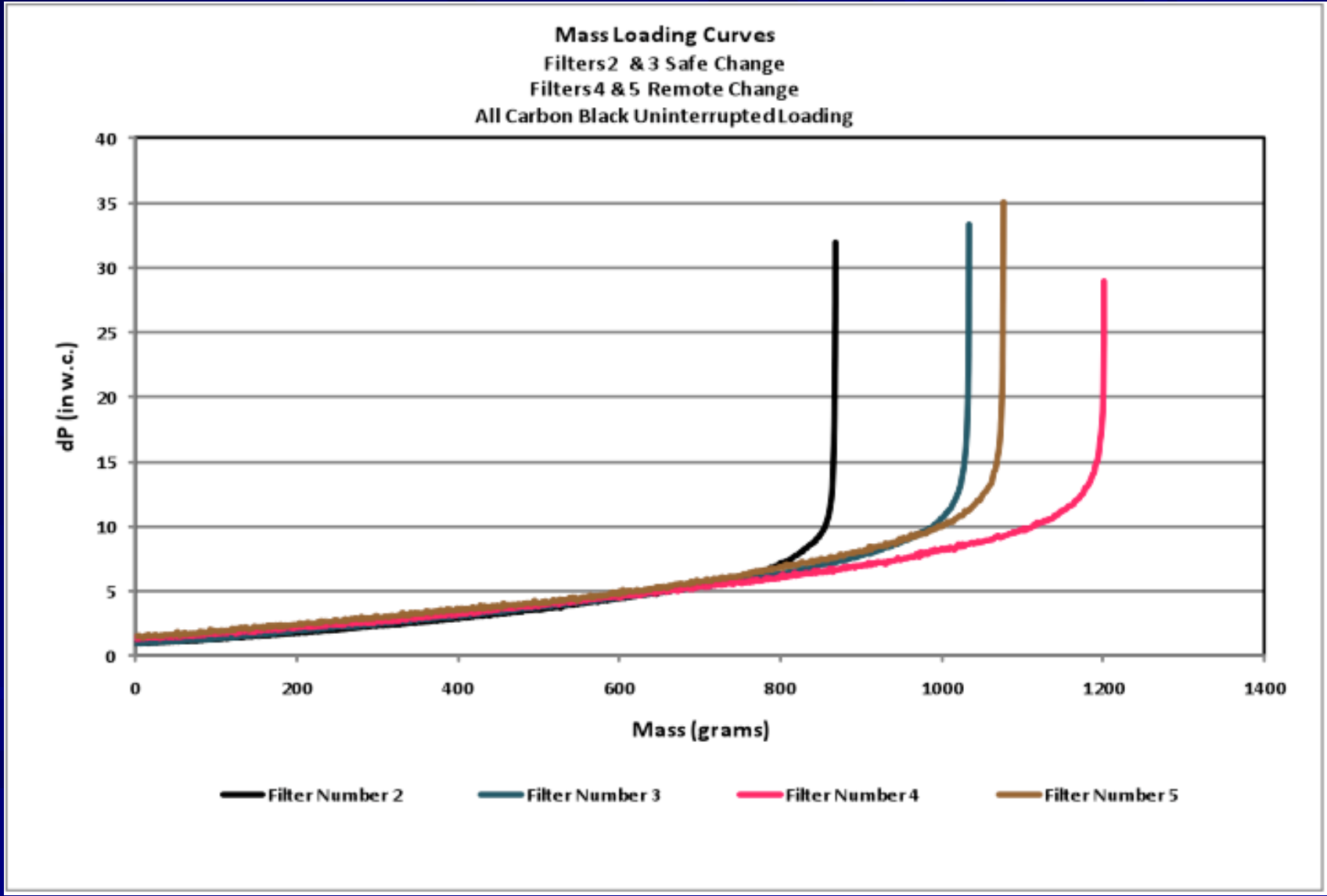
Pleat Collapse



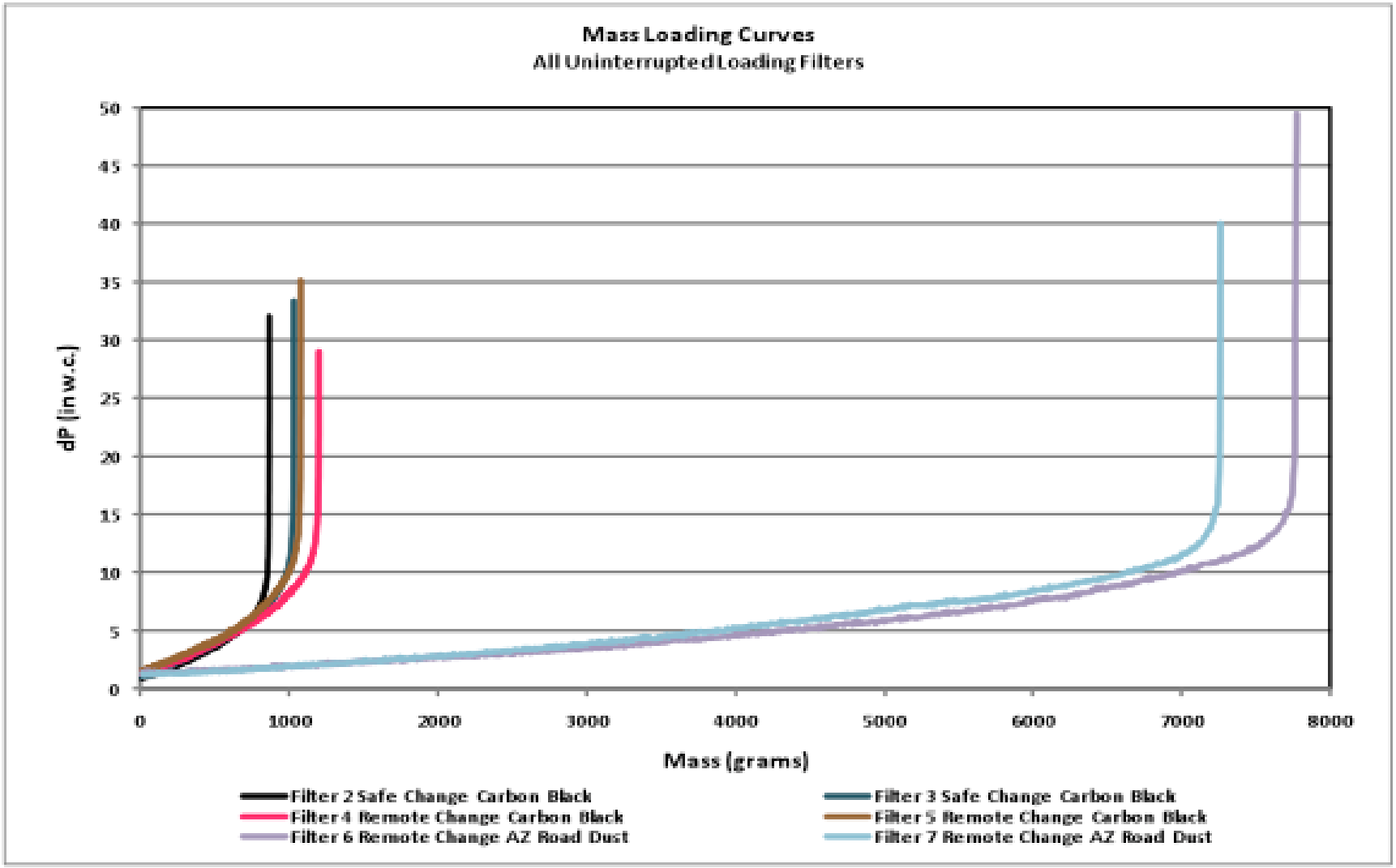
CB Loaded Remote Change Filters



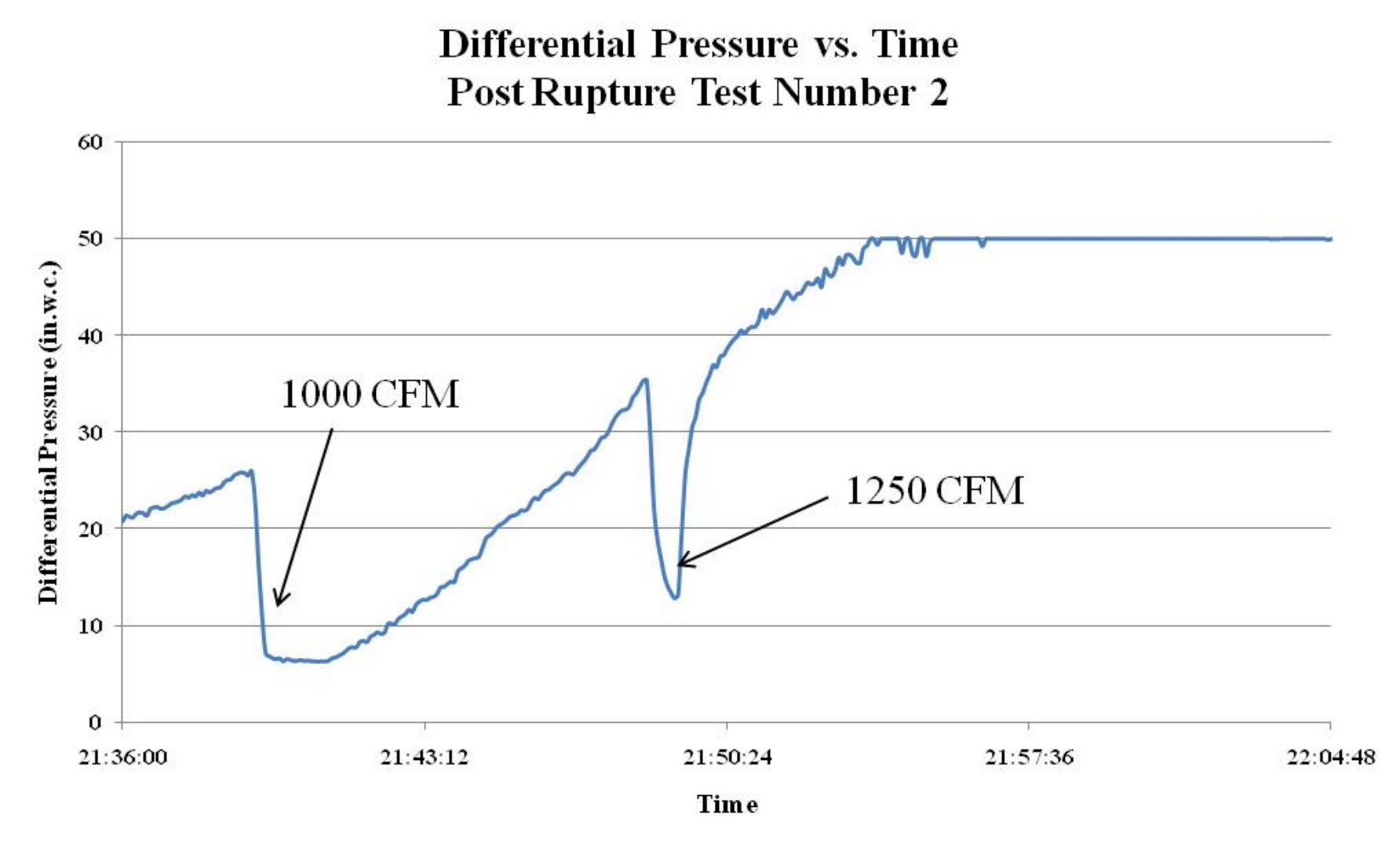
CB Loaded Filters



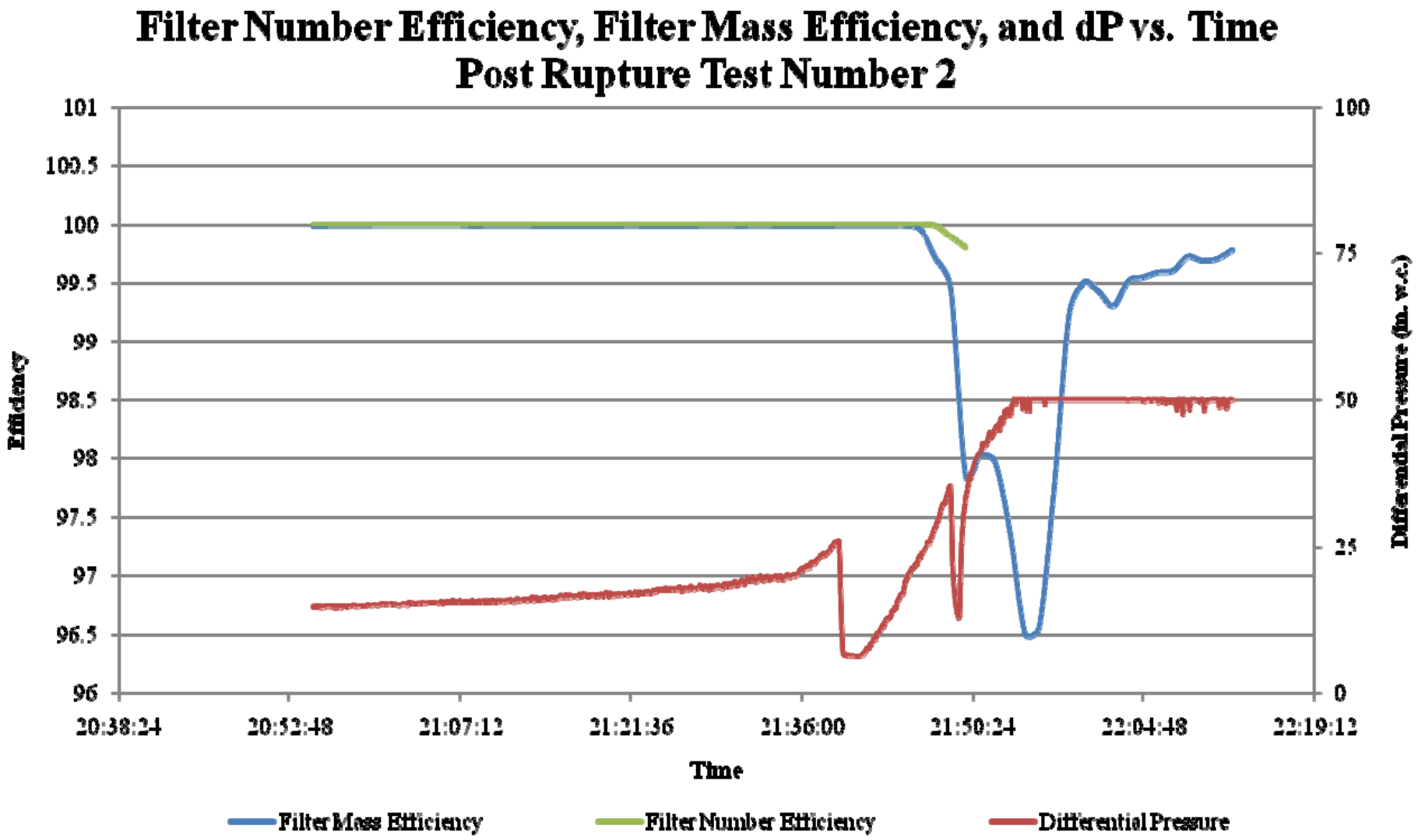
CB and ARD Loading Curves



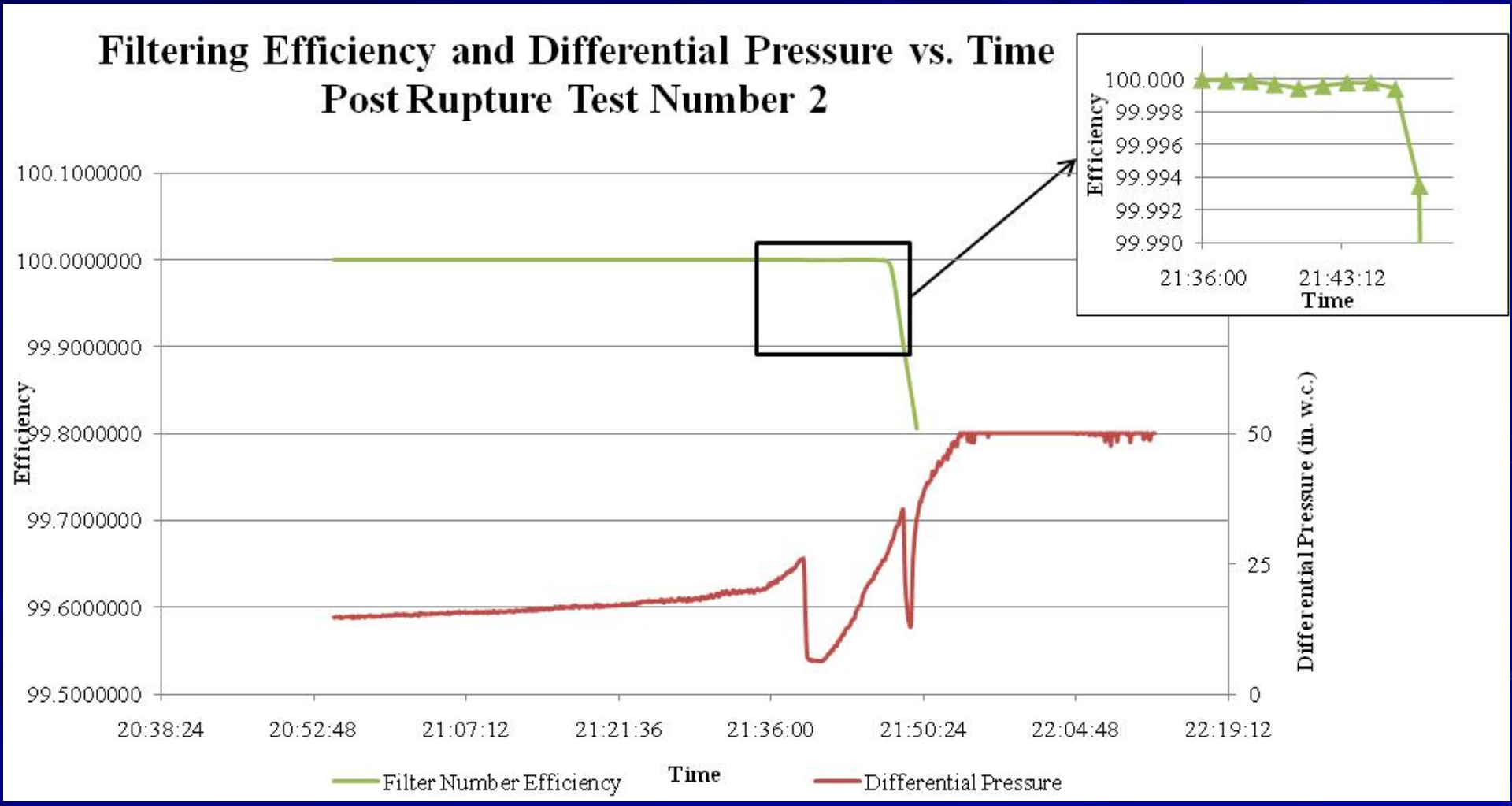
Differential Pressure vs. Time



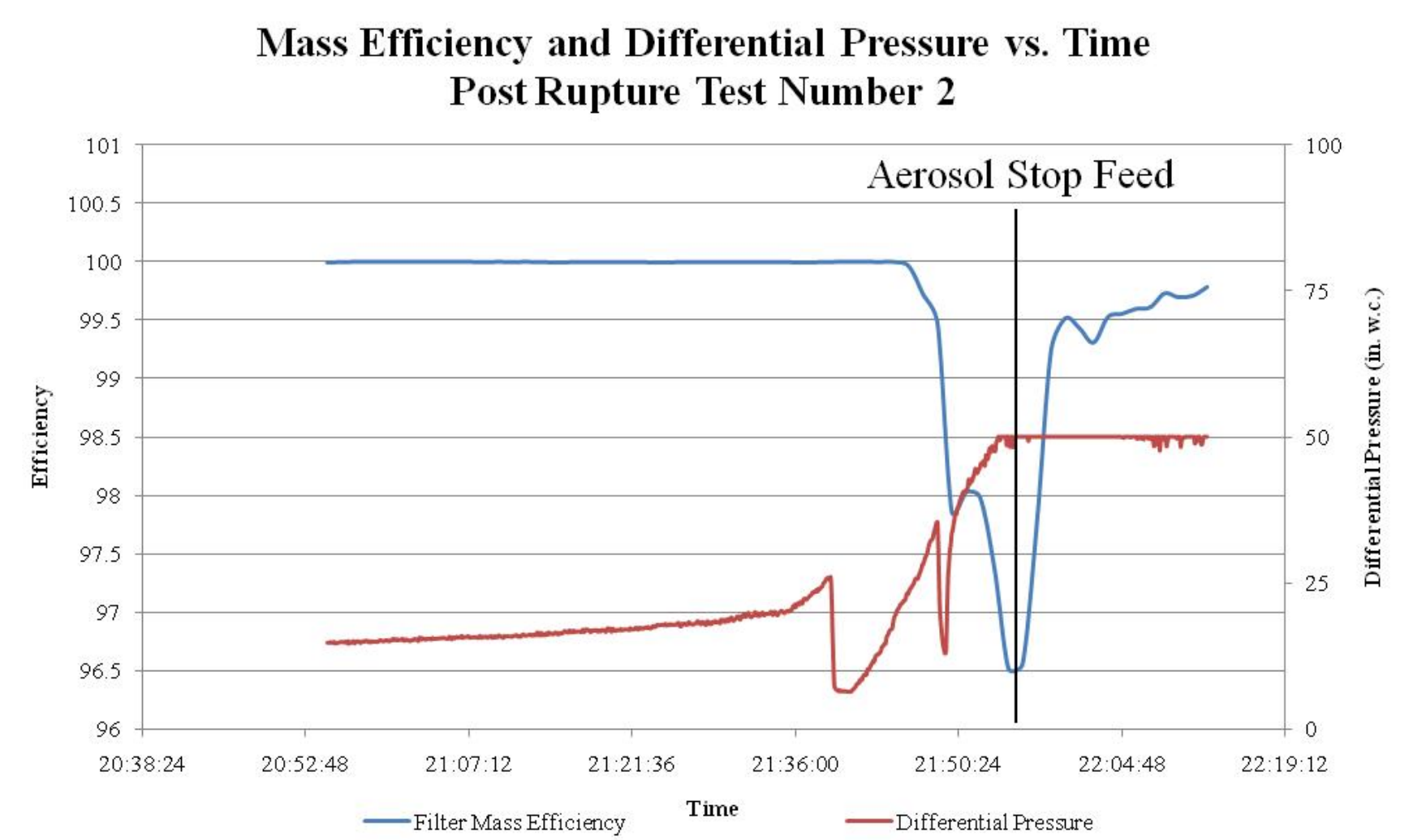
FE, FE mass, dP vs. Time



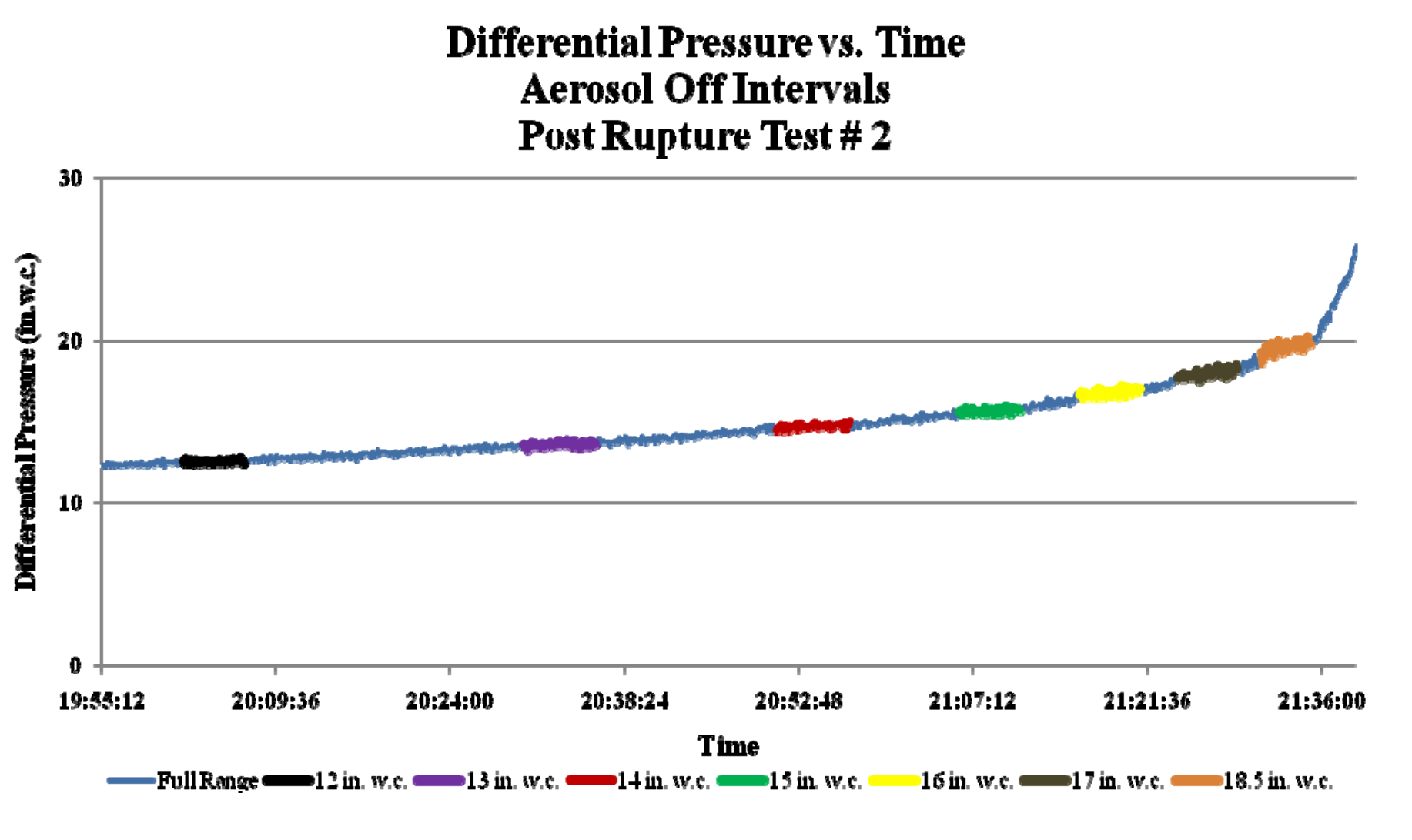
Filtering Efficiency and Differential Pressure vs. Time



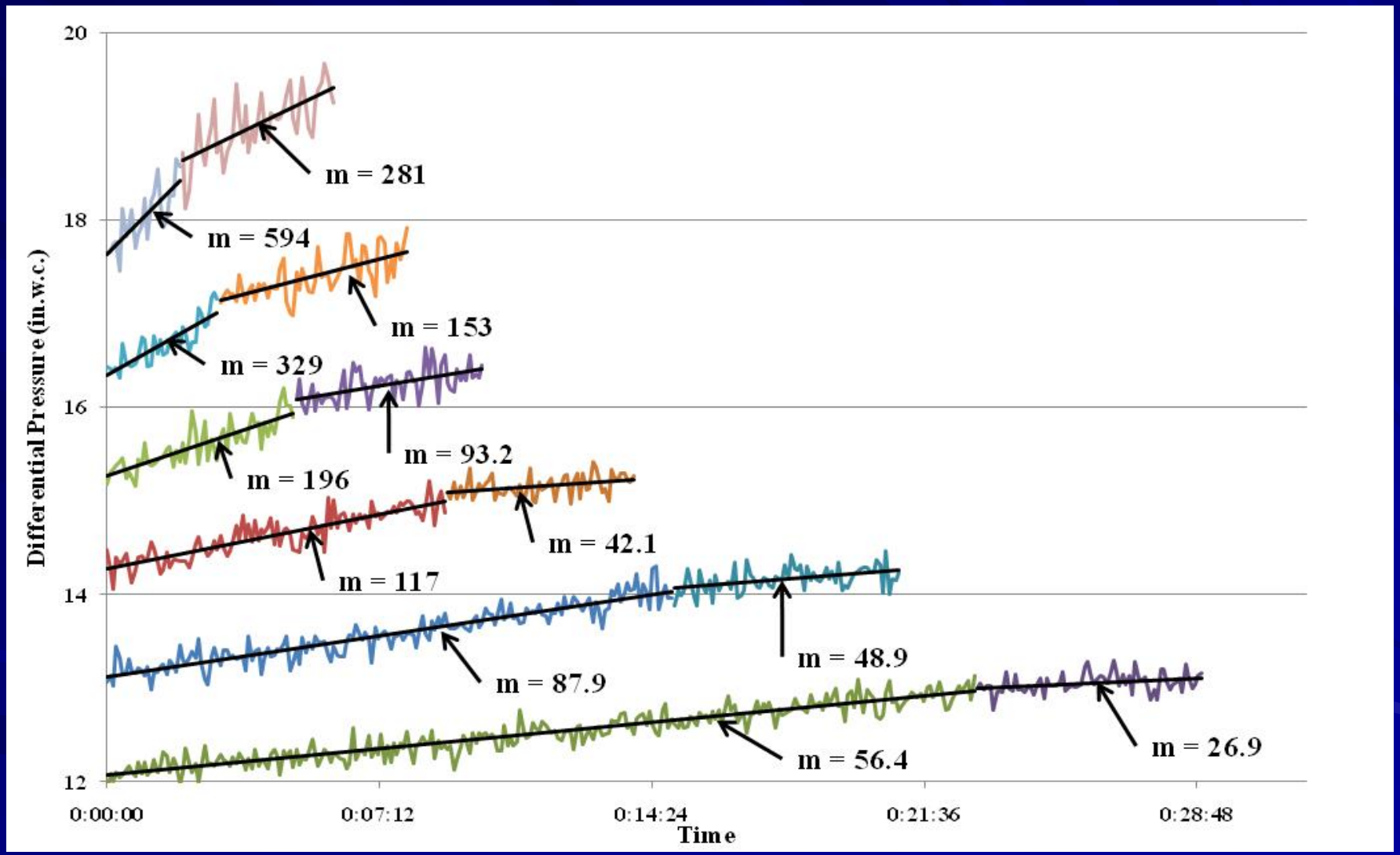
Mass Efficiency and Differential Pressure vs. Time



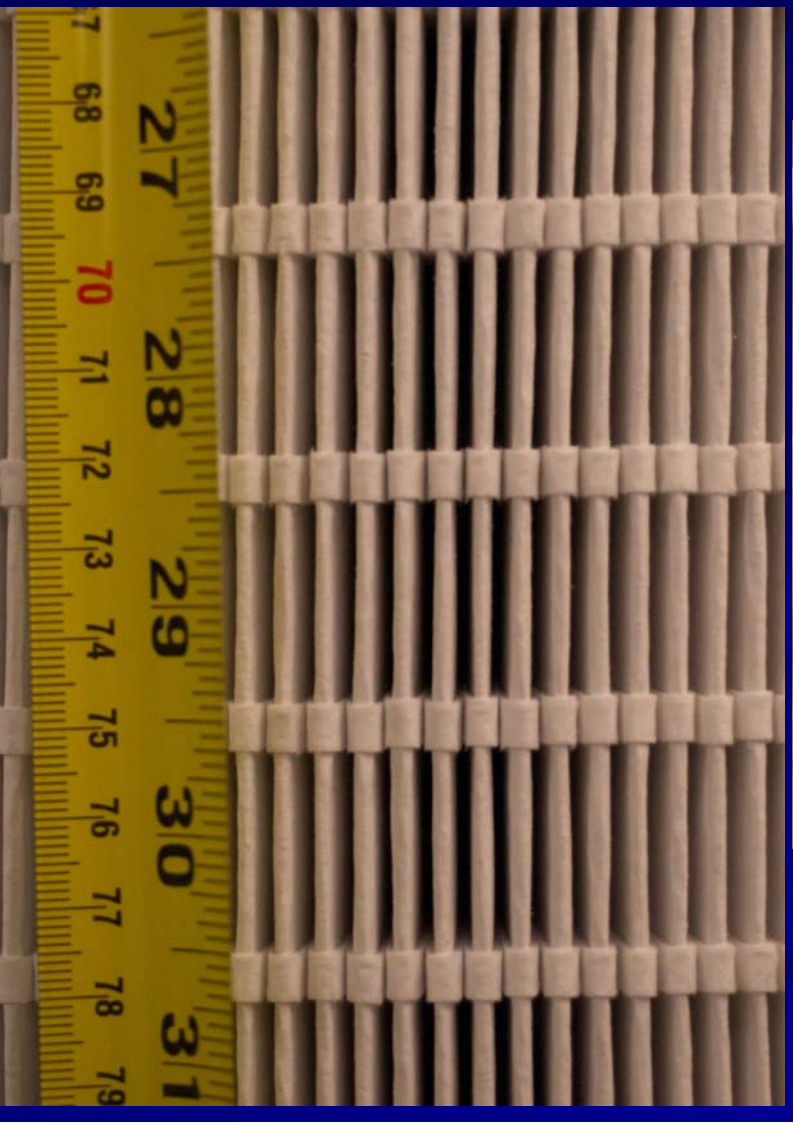
Stability as Fcn of dP

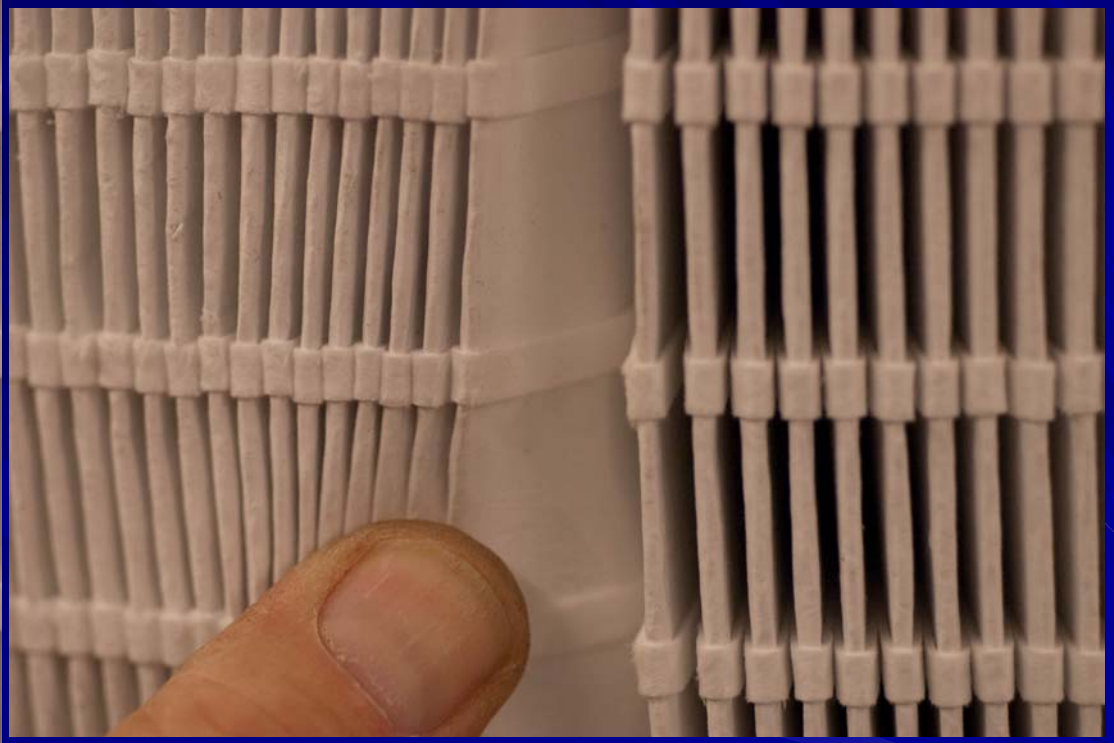


dP Slope Without Aerosol Challenge

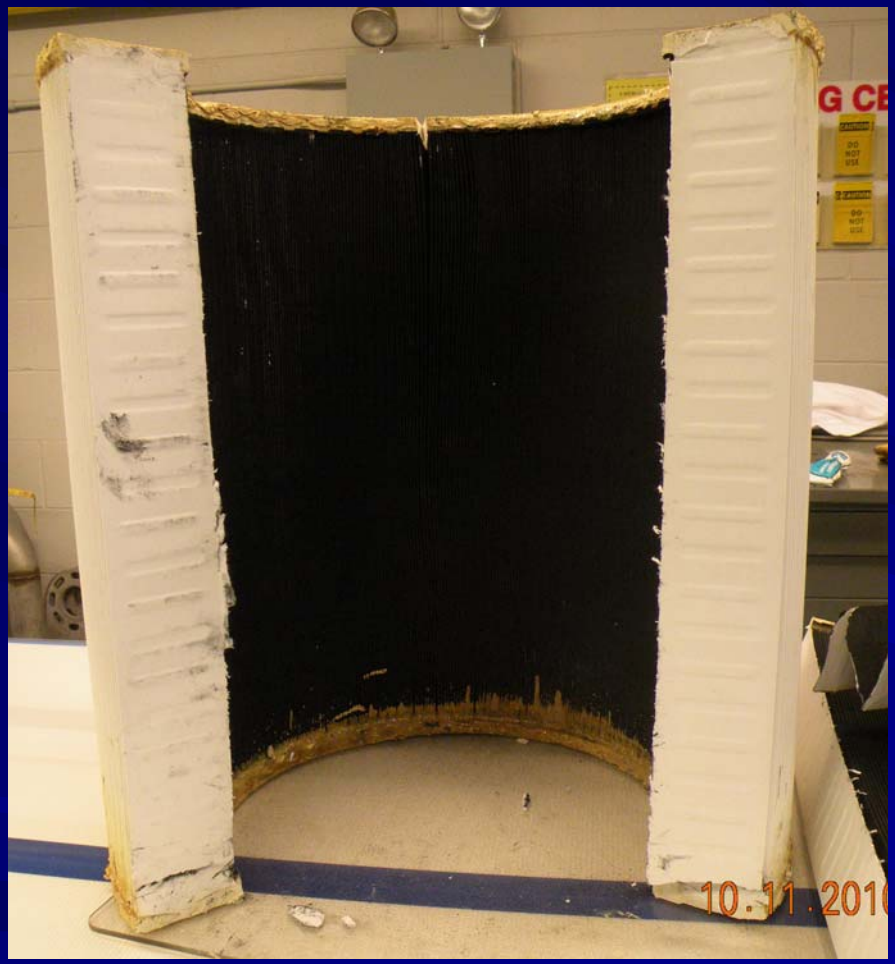


Vokes Filters





Filter Pack Sectioning



Acknowledgements

- Funding for this research activity has been provided by the Department of Energy's Office of Environmental Management under contract number DE-FC30-06EW07040.

Equation for Calculation of Particle Density

Concentration of mass can be found by the following equation :

$$C_m = C_N * \frac{\pi}{6} * D_a^3 * (\rho_0)^{(3/2)} * 1 / \rho_p^{(1/2)}$$

Which, when rearranged, yields the equation to find particle density when the aerodynamic particle diameter is known, such as from an APS.

$$\rho_p = \left\{\frac{C_N}{C_m} * \frac{\pi}{6} * D_a^3 * (\rho_0)^{\left(3/2\right)}\right\}^2$$

Empirical Correlations for Particle Density as a Function of Differential Pressure

The following correlation was arrived at by utilizing experimental data collected from the filter that was loaded with carbon black and weighed at intervals of interest.

This equation allows one to determine the "effective" particle density of carbon black based on the current differential pressure. It presents the equation as a function of the "effective" density that was found for carbon black, ρ =0.939g/cm^3.

$$\rho = 0.939(0.0378 * \ln(dP) + 0.8735)$$

Where dP is in inches w.c. and ρ is in g/cm^3

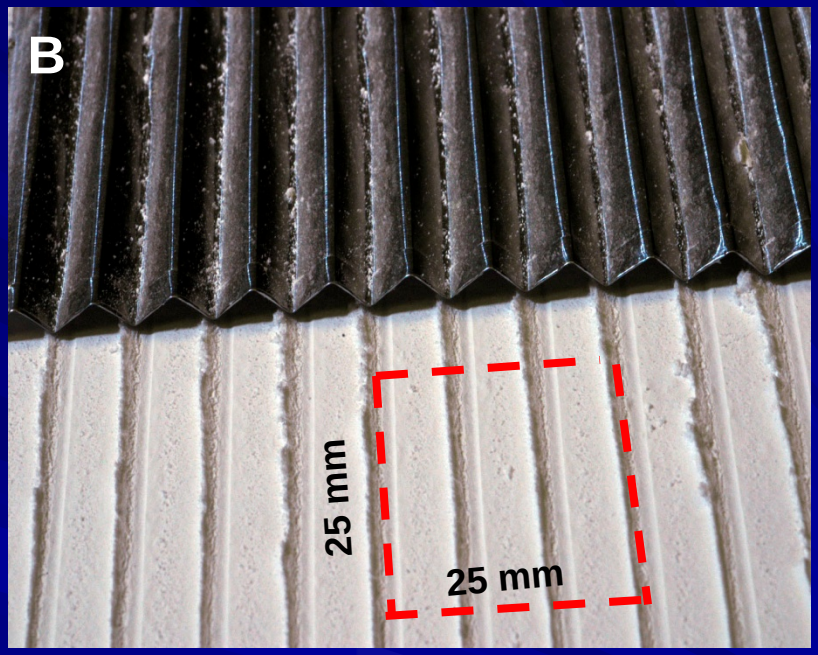
Data for Optimization of Uninterrupted Mass Loading Curves

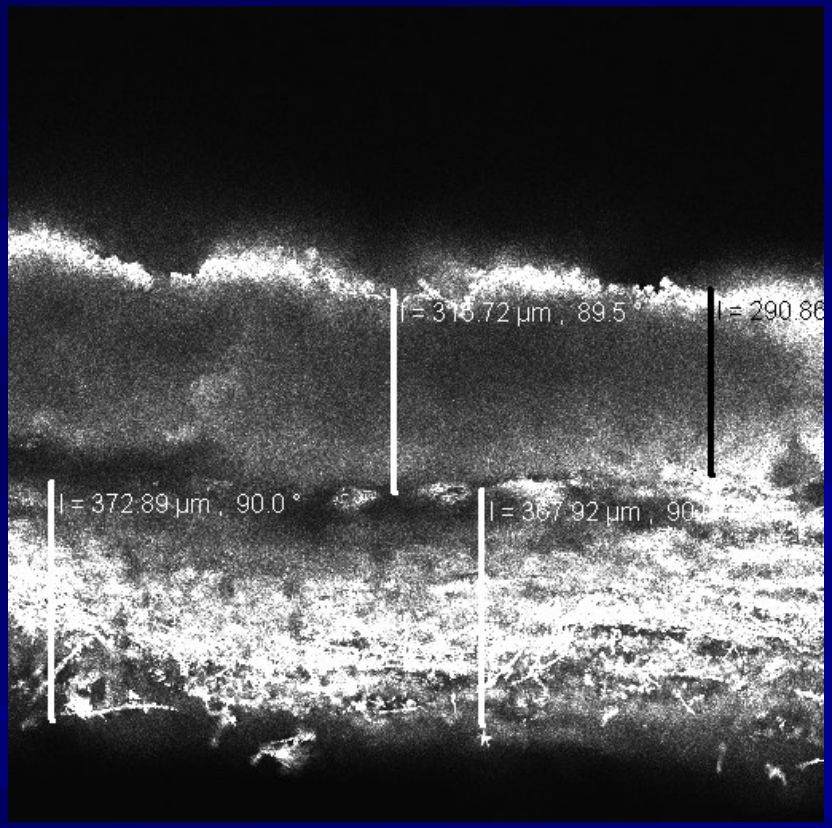
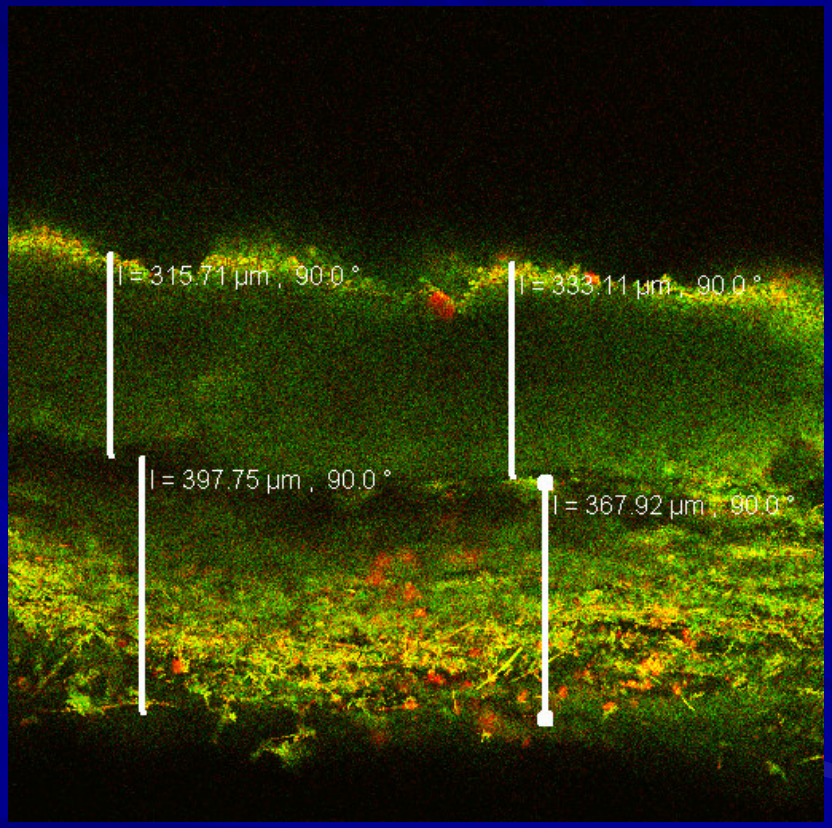
Difference in Actual Mass Gained and Predicted (Calculated) Mass Gained using ρ=0.939g/cm^3

Filter #	Mass Gained (Act)	Predicted Gain	% Error
1 (Adjusted)	1066g	1056g	0.93%
2	874g	879g	0.55%
3	1036g	1030g	0.58%
4	1211g	1196g	1.26%
5	1068g	1070g	0.17%

Filter Disassembly

5 x 5 Grid Coupon Dissection



- ~ 3 – 4 mm was trimmed from the front and back edges of each sheet..

Photomicrographs of Media Cross-section