Assessment of 5 ft/min Requirement for HEPA Filters

By

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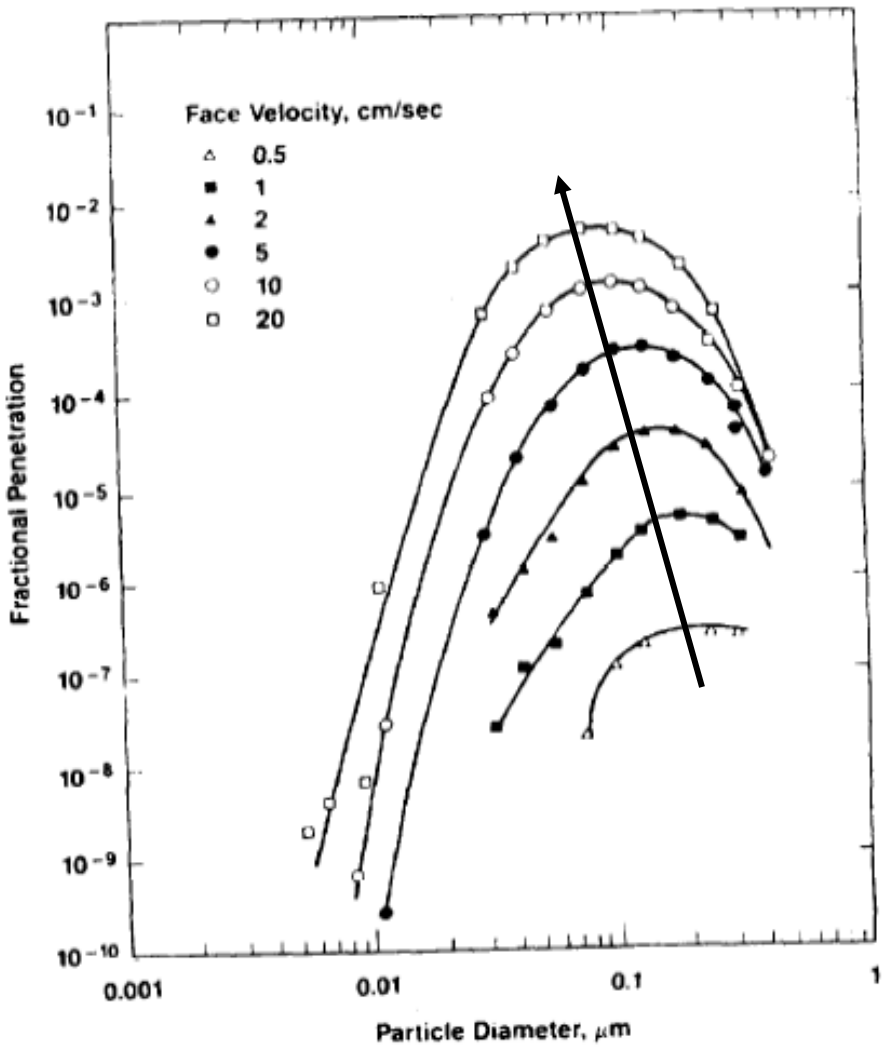
The 5 ft/min requirement for air velocity is redundant for efficiency and pressure drop

- **Although the Velocity affects the filter efficiency and pressure drop, these parameters are required measurements.**

- **Having the 5 ft/min requirement for efficiency and pressure drop is redundant.**

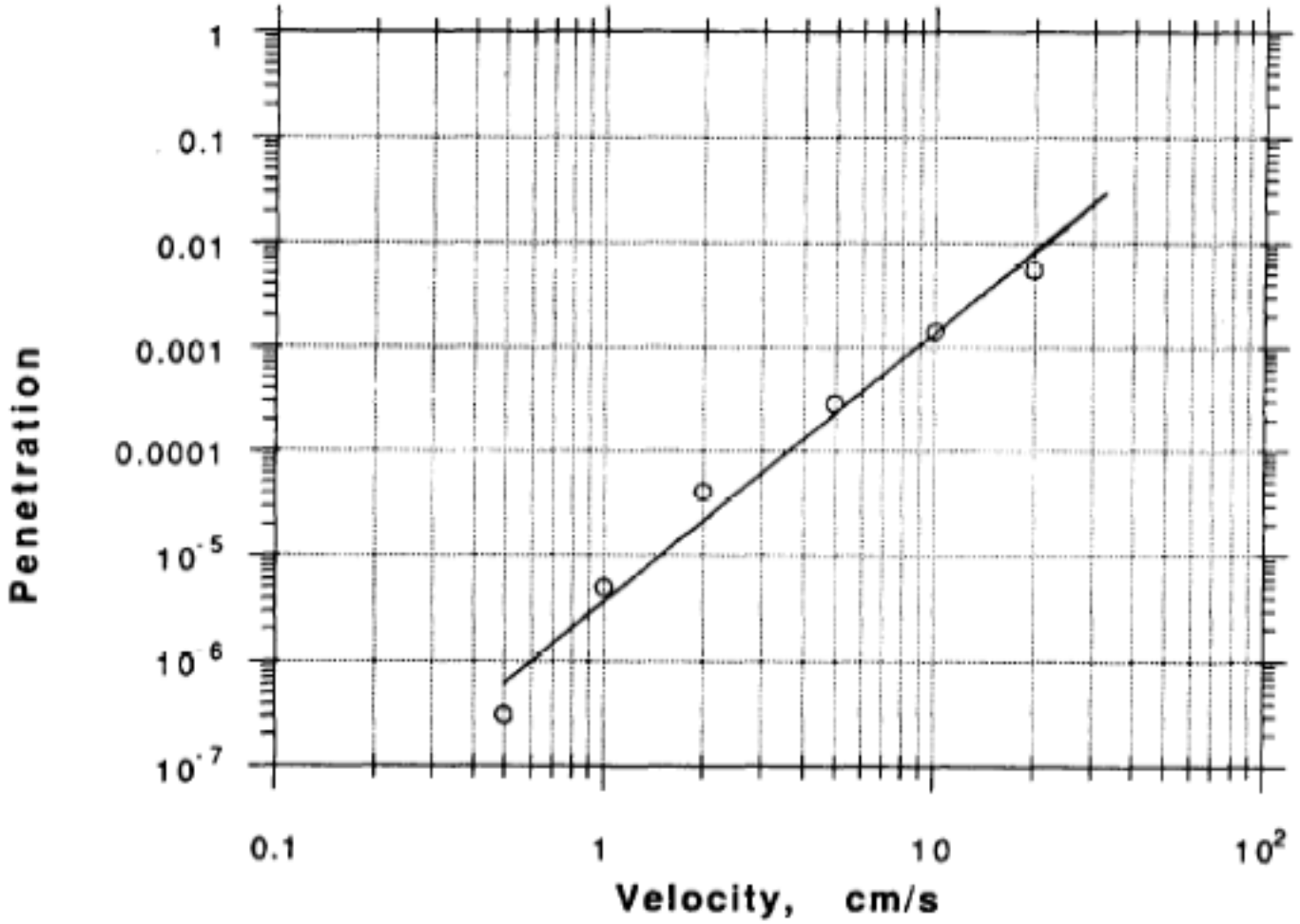
- **The 5 ft/min requirement was useful in the past to ensure a minimum particle loading, but it is not effective for new high media area filters.**

Increased air velocity increases HEPA filter penetration



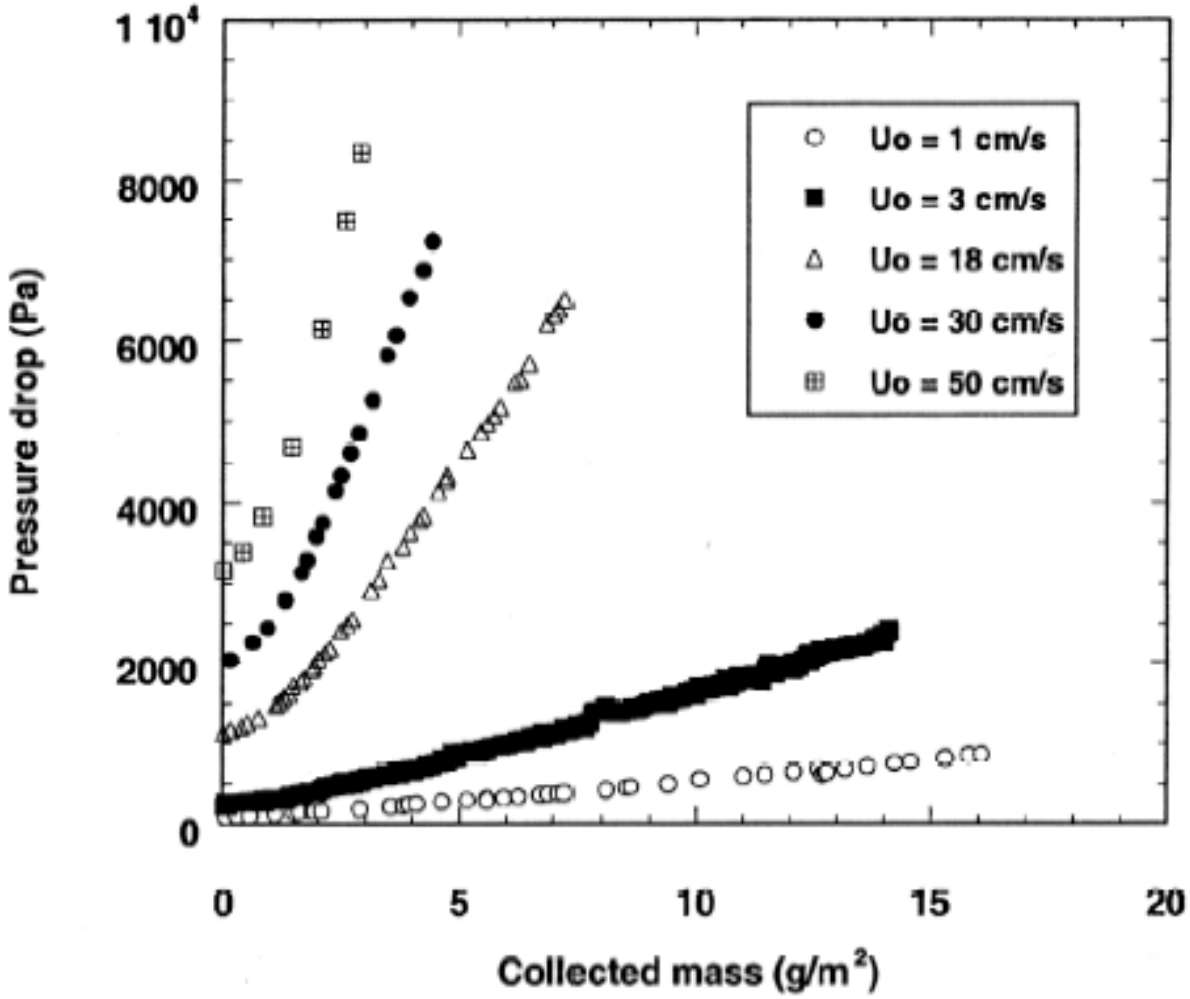
Bergman (1994)
23rd NACC

Increased air velocity increases HEPA filter penetration



Bergman (1994) 23rd NACC

Increased air velocity increases HEPA filter pressure drop and decreases particle loading



Thomas (2001) Chem. Eng. Sci.

The 5 ft/min air velocity limit became a surrogate criterion for ensuring minimum HEPA loading

- The efficiency and pressure drop are measured and do not require the velocity limit.
- HEPA particle loading is not measured.
- It was assumed that the velocity limit would ensure a minimum particle loading.
- This assumption is not valid for HEPA filters with increasing filter media.
- The new HEPA filters with large media area have restricted the volume available for particle loading.

Pressure drop is the sum of the viscous flow resistance of the medium and the channel flow

$$\Delta P_t = \Delta P_m + \Delta P_c$$

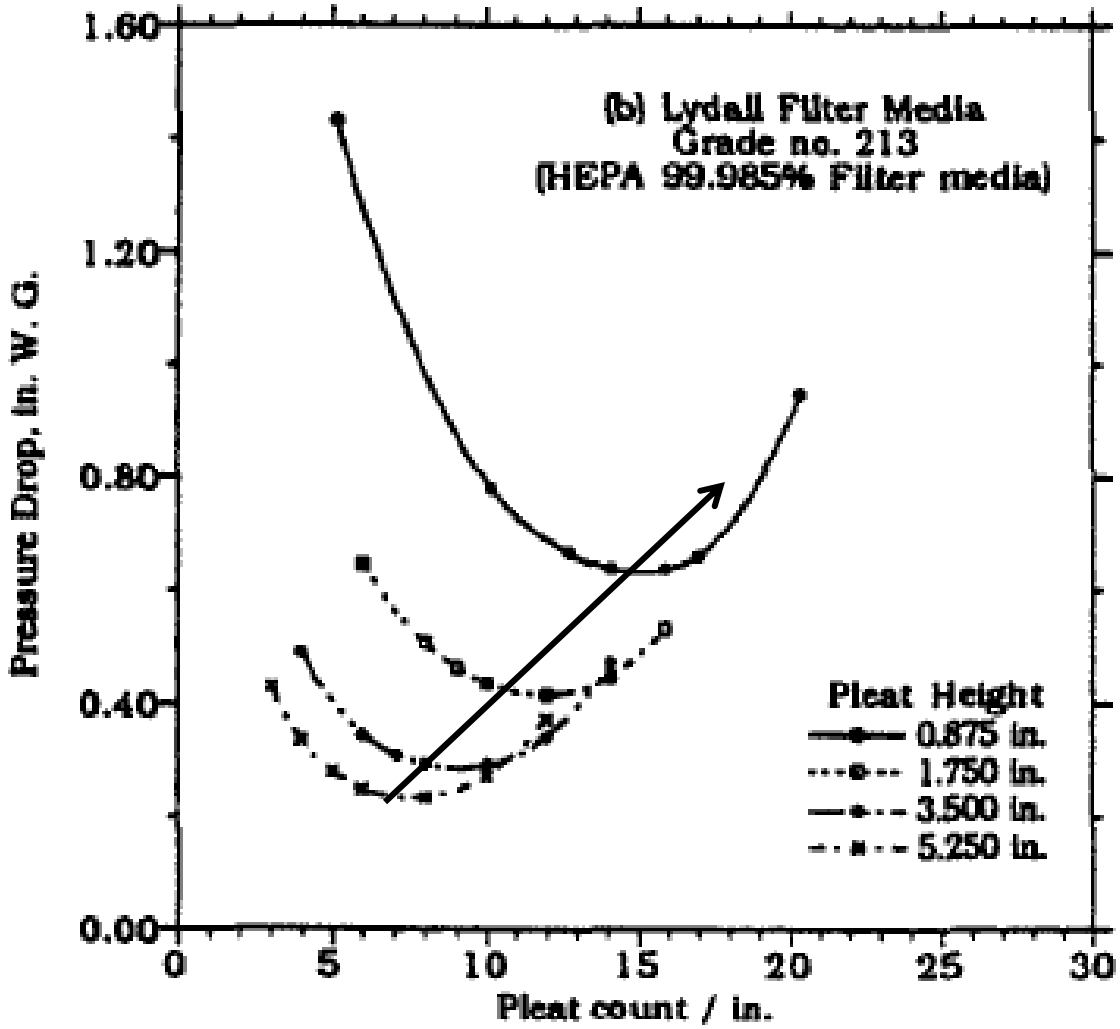
Increasing the filter area or number of pleats decreases the medium resistance and increases the channel resistance

$$\frac{\Delta P_c}{\Delta P_m} \sim \frac{8}{KL}\left(\frac{L}{W-t}\right)^3$$

L = Pleat height
W = one half the pleat width
t = filer medium thickness
K = constant for filter medium

Chen et al 1995, J. Aerosol Sci.

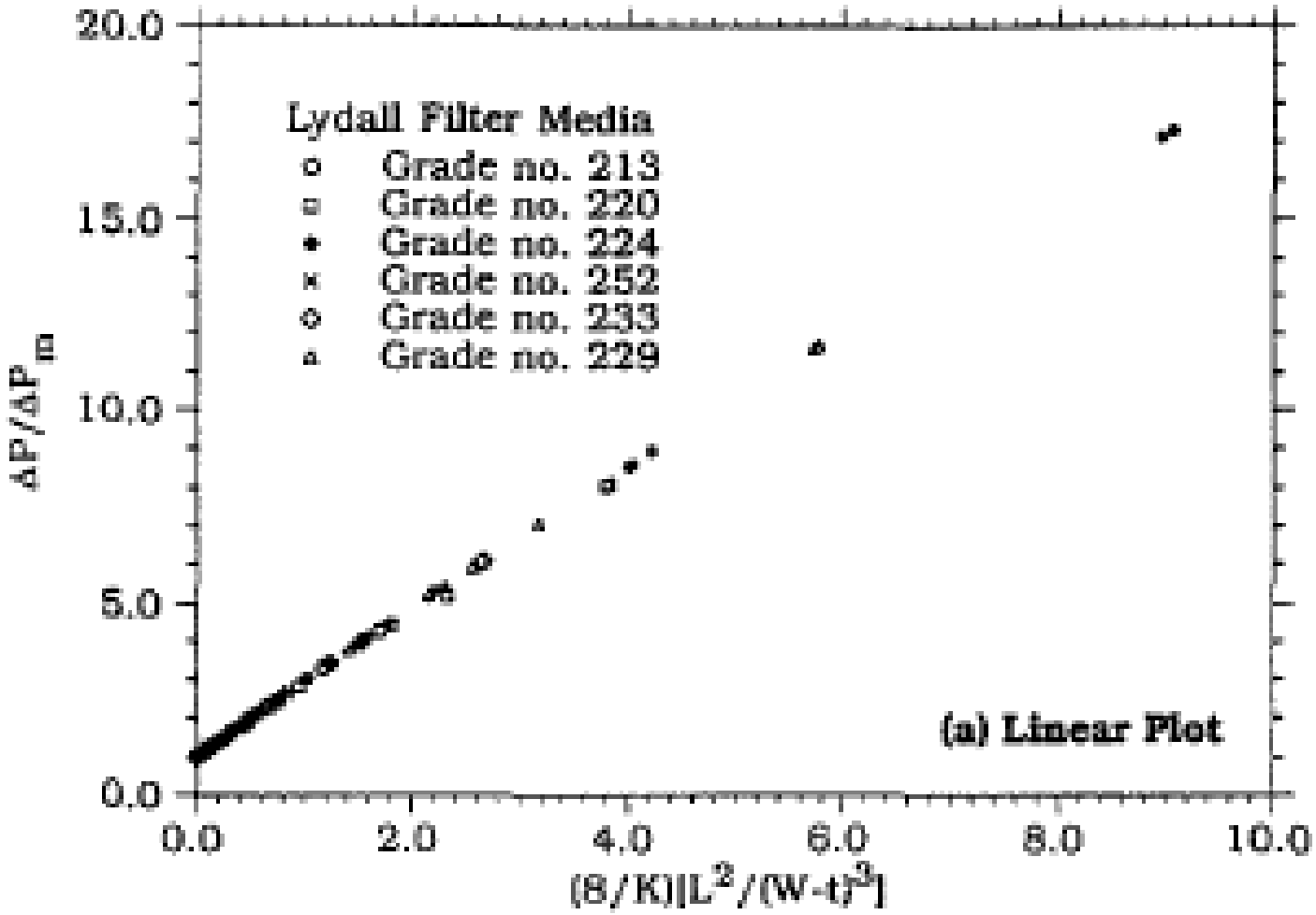
HEPA filters have a minimum in pressure drop with pleat counts



Min. ΔP shifts to increasing pleats with smaller pleat height

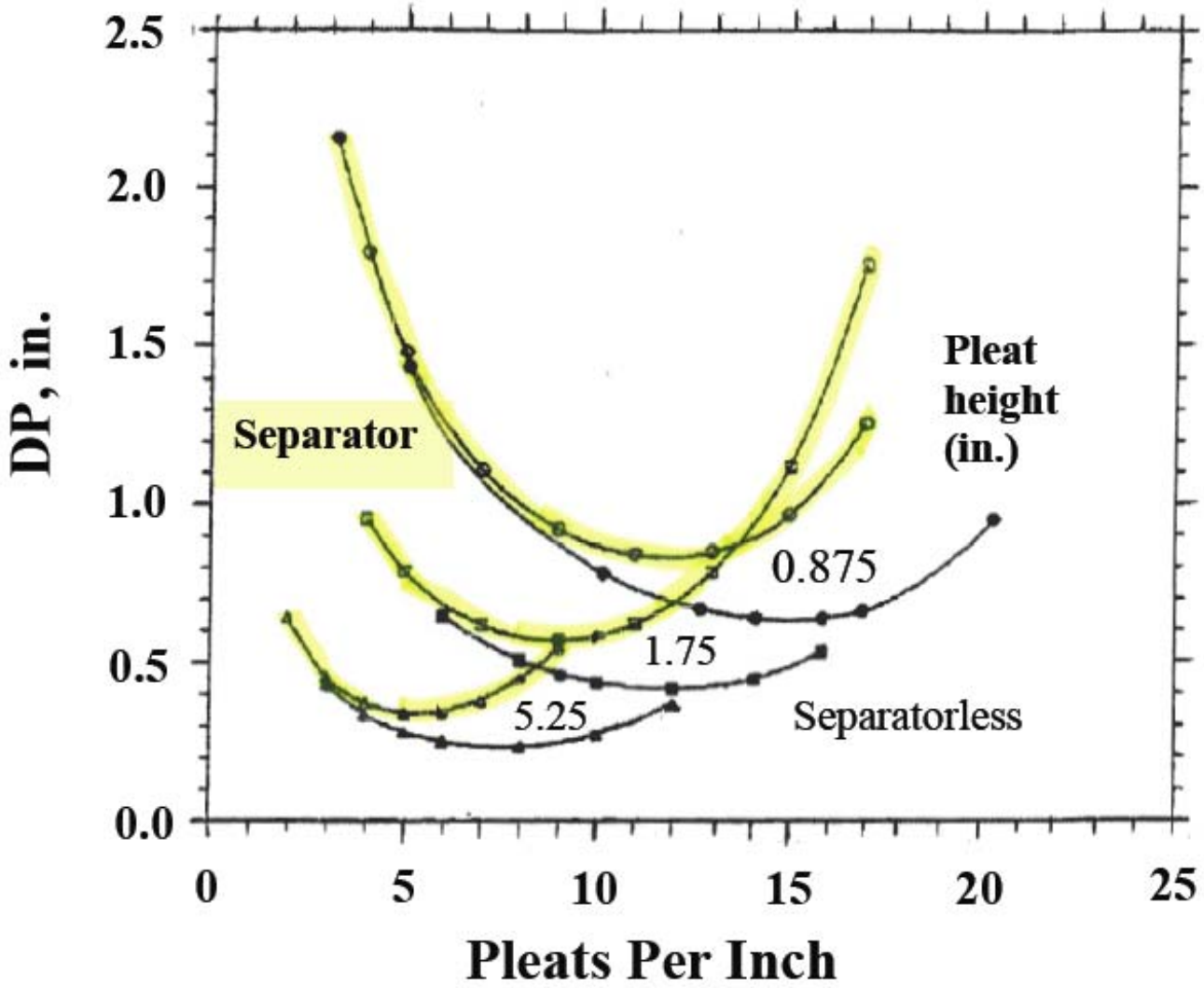
Chen et al 1995, J. Aerosol Sci.

Pressure drop for various media increases linearly with pleating parameter



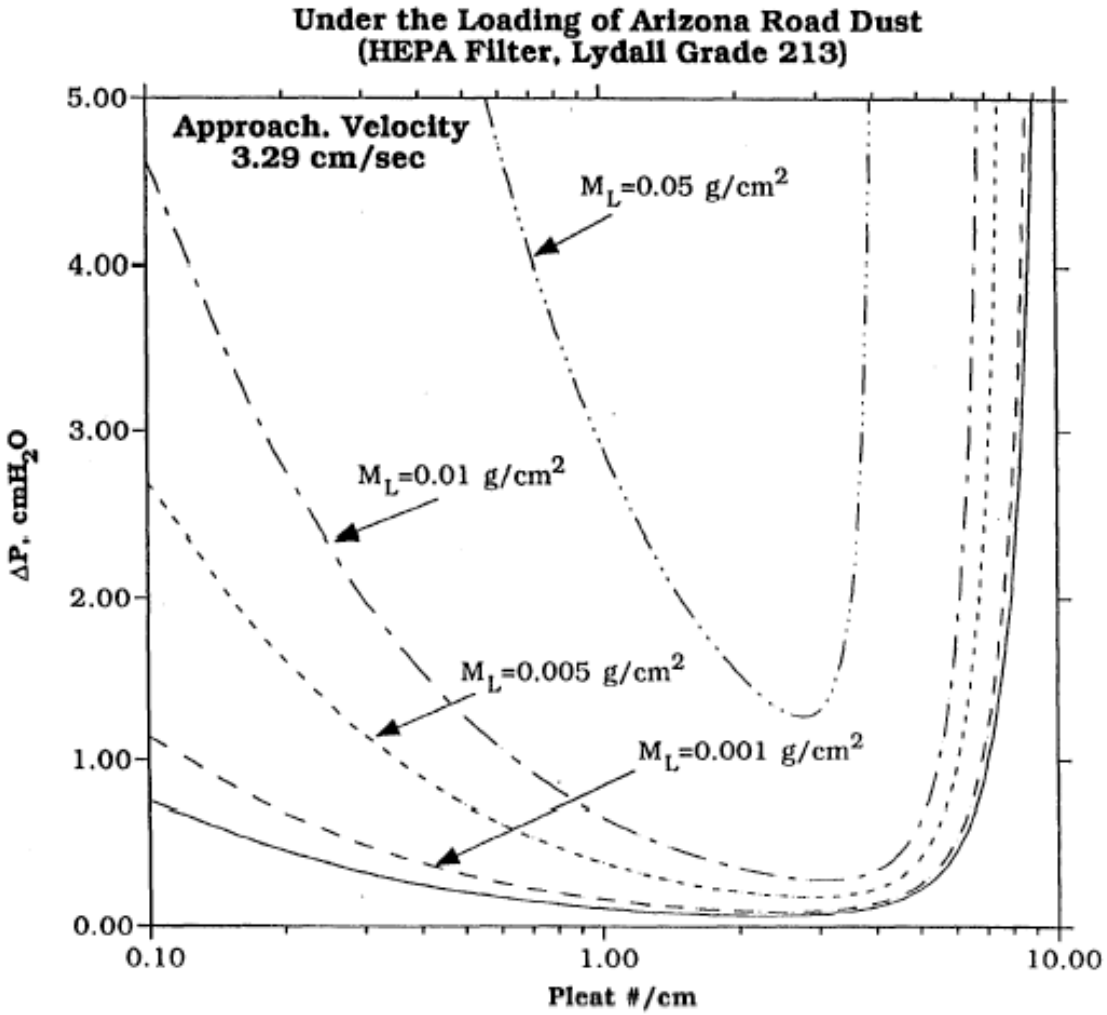
Chen et al 1995, J. Aerosol Sci.

Pressure drop increases more with separator filters than with separtorless filters



Chen et al 1994, Proc. Annual AFS Society

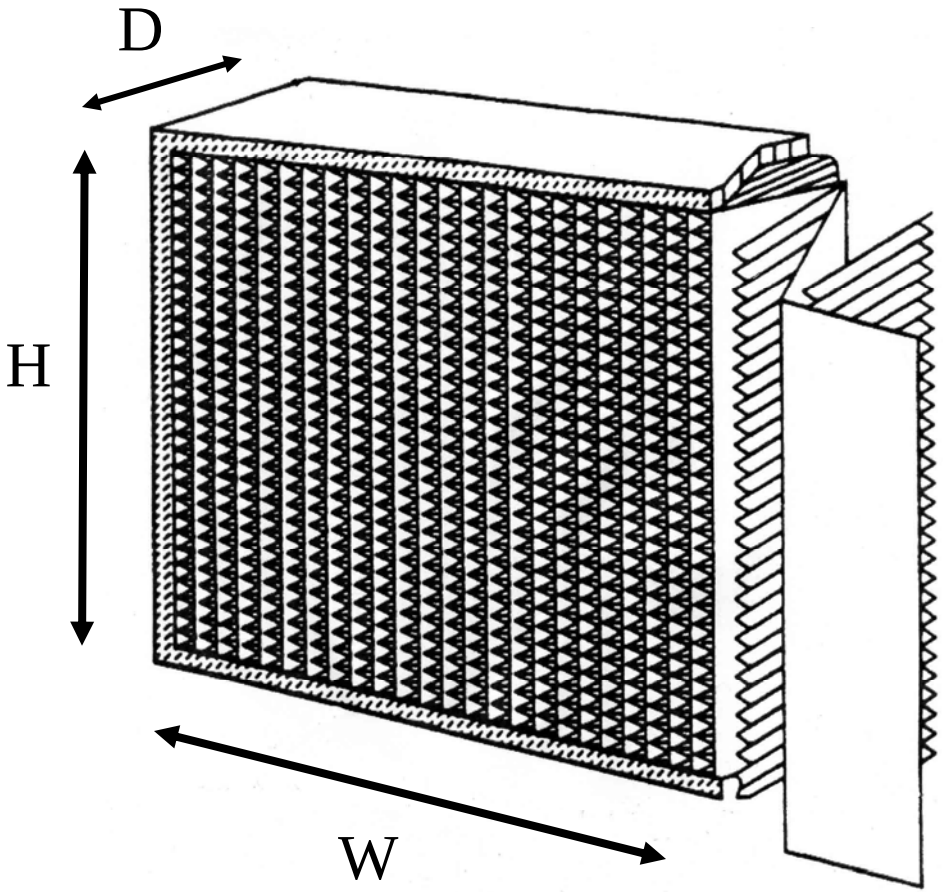
Particle loading shifts the minimum pressure drop to smaller pleat sizes

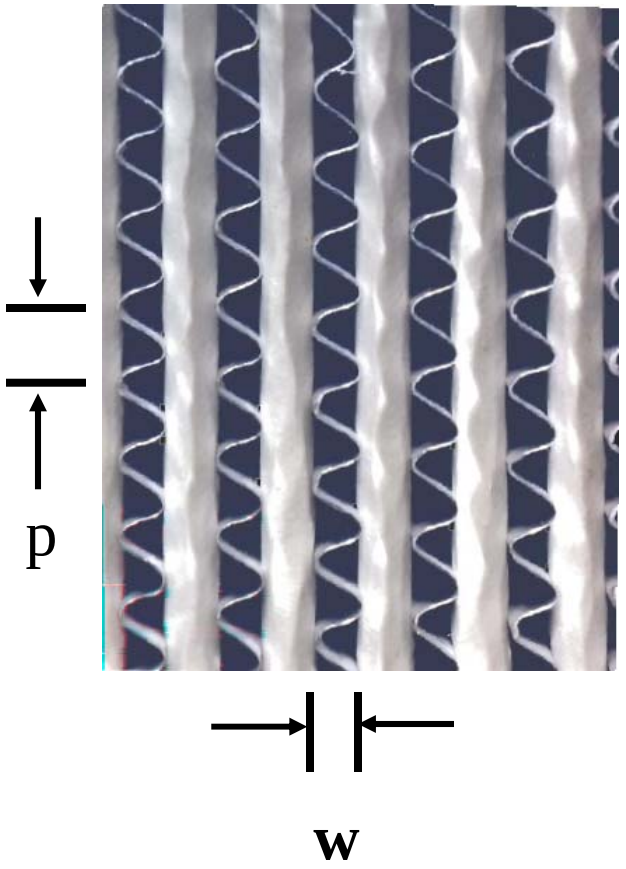


Filter volume capacity is computed from the filter structure

medium thickness = T

separator thickness = t





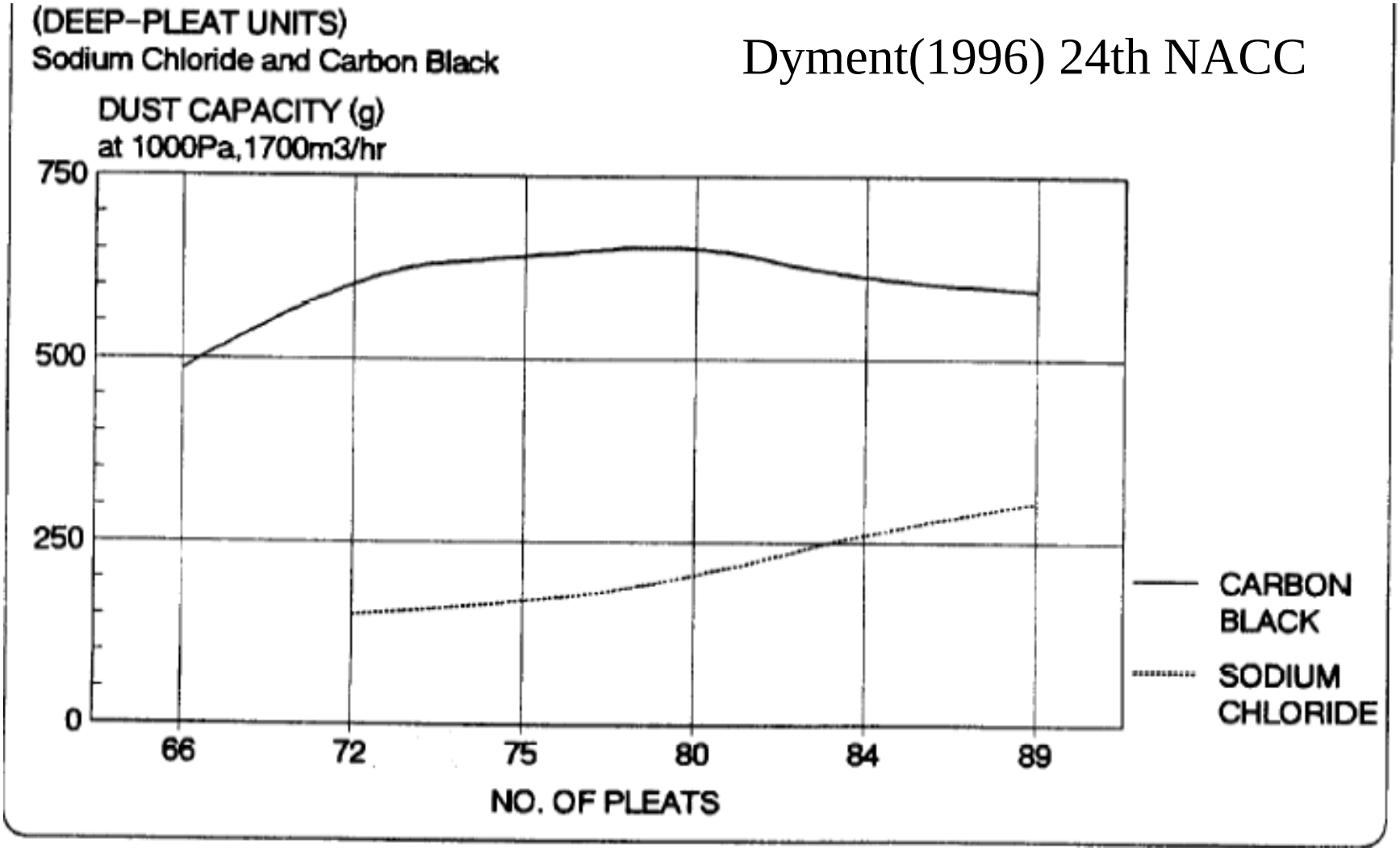
Filter volume capacity is computed from the filter structure

$$Pleat\ Volume = V_p = \left(w\,D - T\right) H - V_s$$

$$Separator\ Volume = V_s = \frac{2HDt}{p}\sqrt{w^2 + p^2/4}$$

$$Filter\ Volume\ Capacity = W\ /(w + T)$$

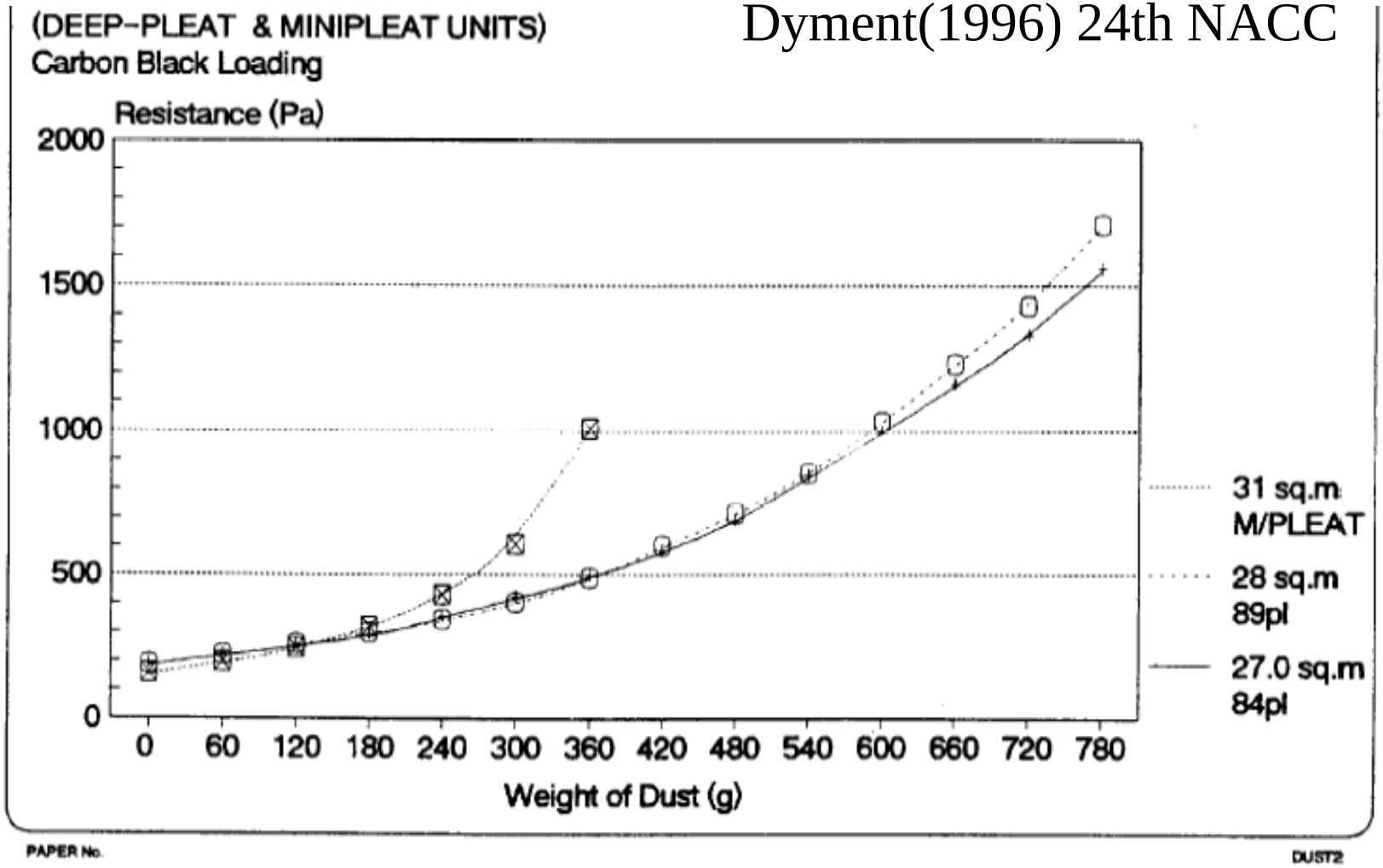
Studies have shown increasing pleats can lead to decreased particle loading



Dyment(1996) 24th NACC

Increasing filter area can lead to decreased particle loading

Dyment(1996) 24th NACC



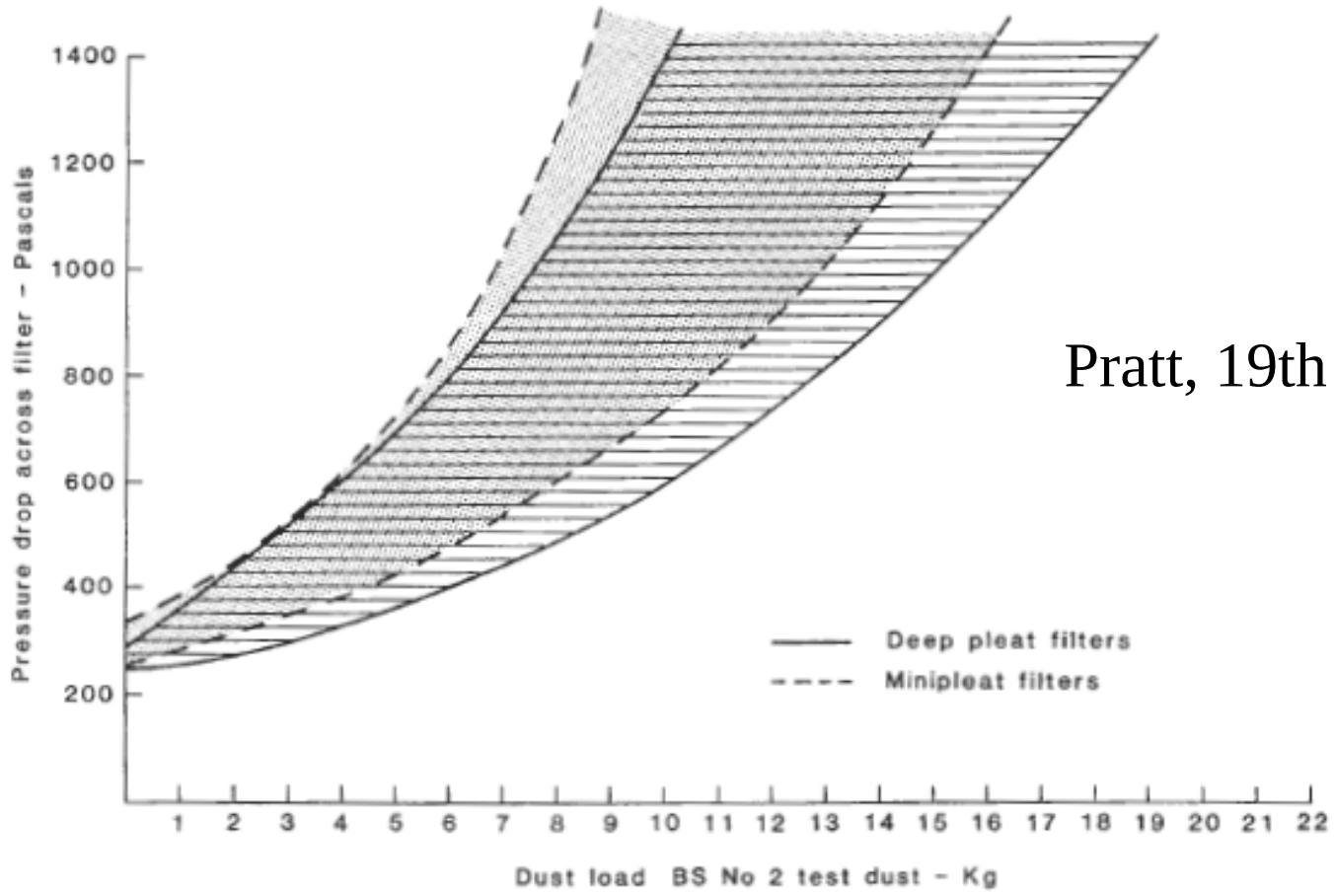
Additional complications in filter loading

•Dyment (1996) found that large particles (carbon black) can block the inlet channels of the HEPA filter and thereby lead to non-uniform particle deposits.

• The pressure drop due to particle loading is dependent on particle size and density.

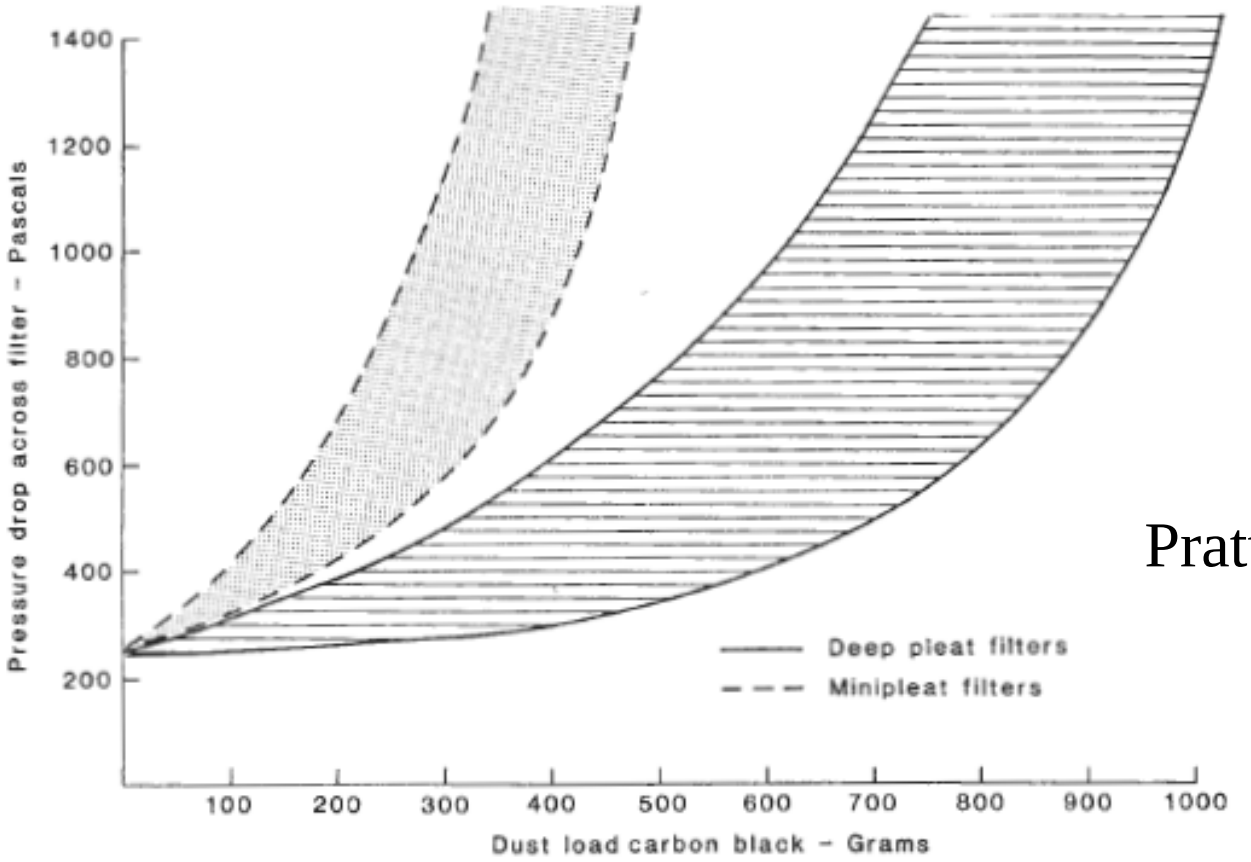
•Moisture can have a major effect on the resulting particle deposits and pressure drop.

Loading tests with alumina dust is not strongly affected by filter area



Pratt, 19th NACC

Loading tests with carbon black are strongly affected by filter area



Pratt, 19th NACC

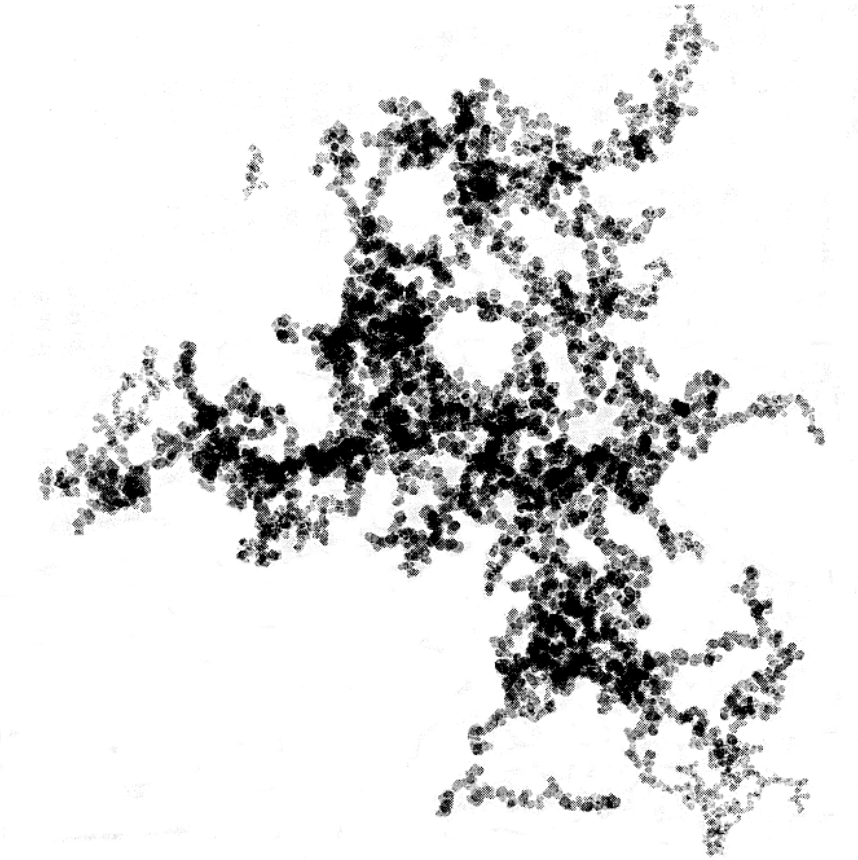
Filter loading model accounts for the key experimental parameters

$$\left(\Delta P_m - \Delta P_{m0}\right)\frac{\rho_{pD} D_{pf}}{V_m} = 64 C_u \frac{\mu \sqrt{\alpha_F}}{D_F}\ \frac{M}{A}$$

particle fiber model, Bergman (2006) 29th NACC

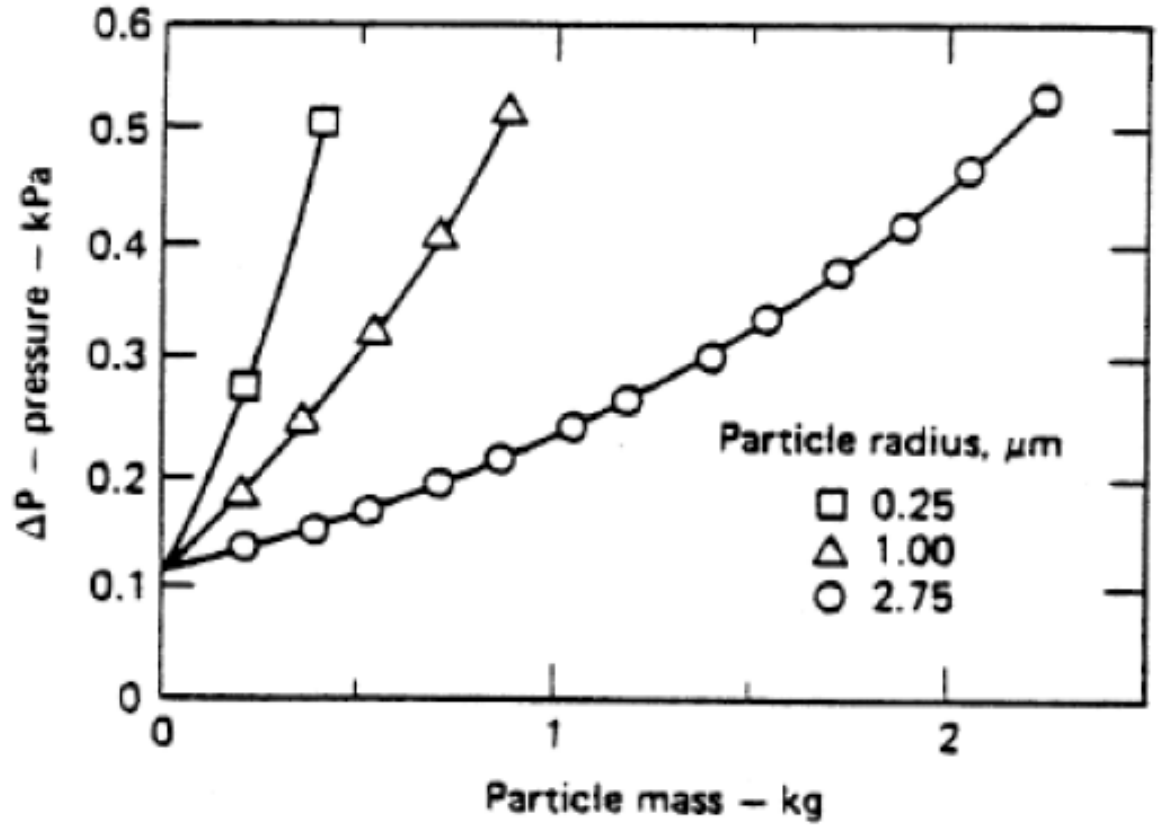
The model predicts higher pressure drops with higher mass deposits, higher air velocities, smaller particle diameters, and smaller particle densities.

Low density particles increase filter plugging



The lower density deposits may account for the increased plugging by carbon black compared to test dust.

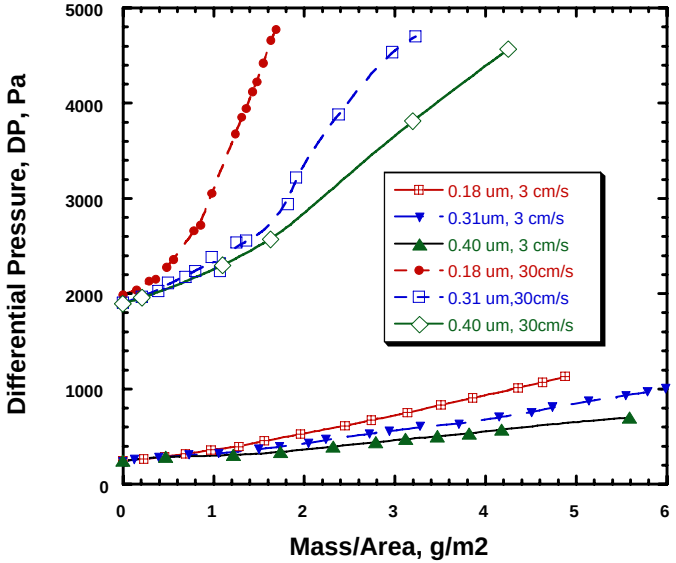
Small particles cause greater increase in pressure drop than larger particles



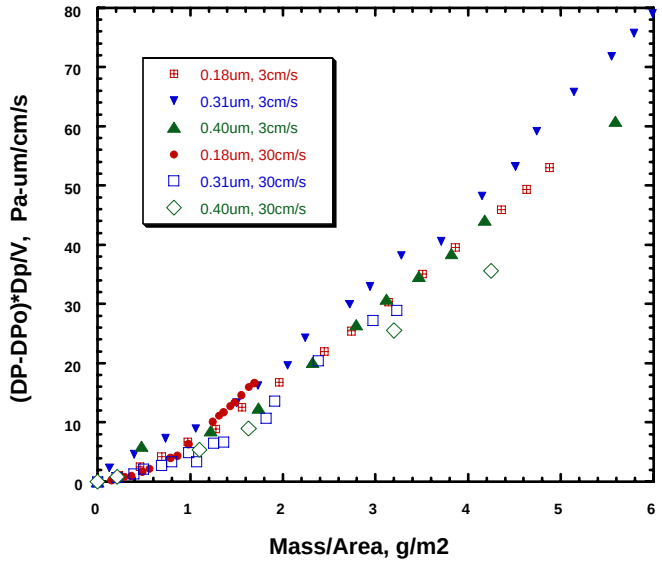
Bergman (2006)
29th NACC

Model validation

Loading studies on HEPA media validate particle fiber model for media velocity and particle size



Loading data for HEPA media

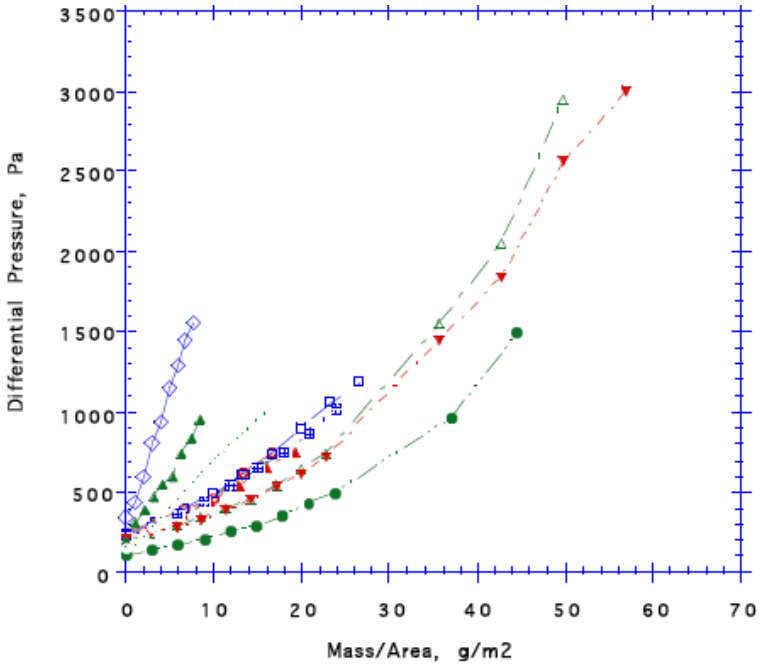


Normalized data is

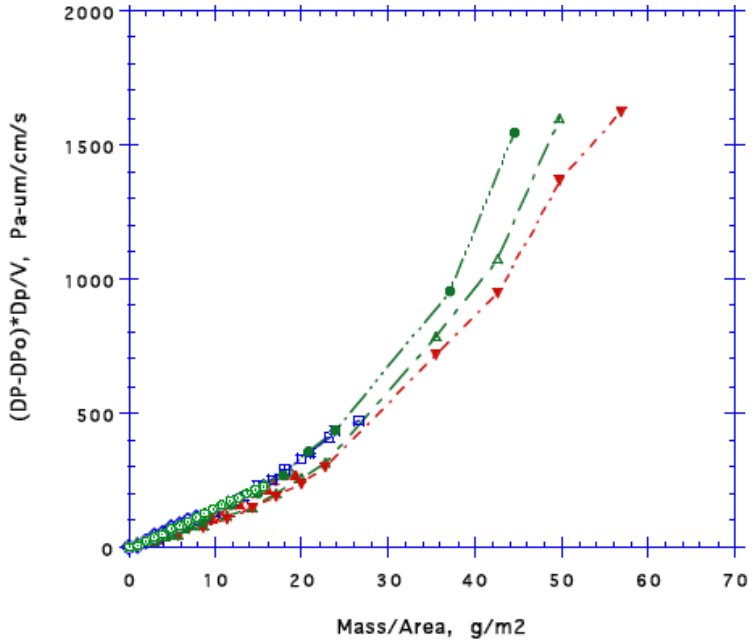
- independent of media velocity and particle size
- weakly dependent on particle mass

Model validation

Loading studies on HEPA filters validate particle fiber model for media velocity and particle size



Loading data for HEPA filter



Normalized data is

- independent of media velocity and particle size
- strongly dependent on particle mass

Conclusions

• The 5 ft/min air velocity requirement does not improve the filter efficiency or pressure drop, both of which are measured.

•The 5 ft/min requirement is a surrogate for the lack of a particle loading test.

•When manufacturers use additional media area to achieve the 5 ft/min requirement for HEPA filters, the resulting filter can have significantly reduced particle loading.

•A separate particle loading test should be developed to replace the ineffective 5 ft/min requirement.