High Efficiency Particulate Air Filters as Structural Elements in Nuclear Air Cleaning Systems

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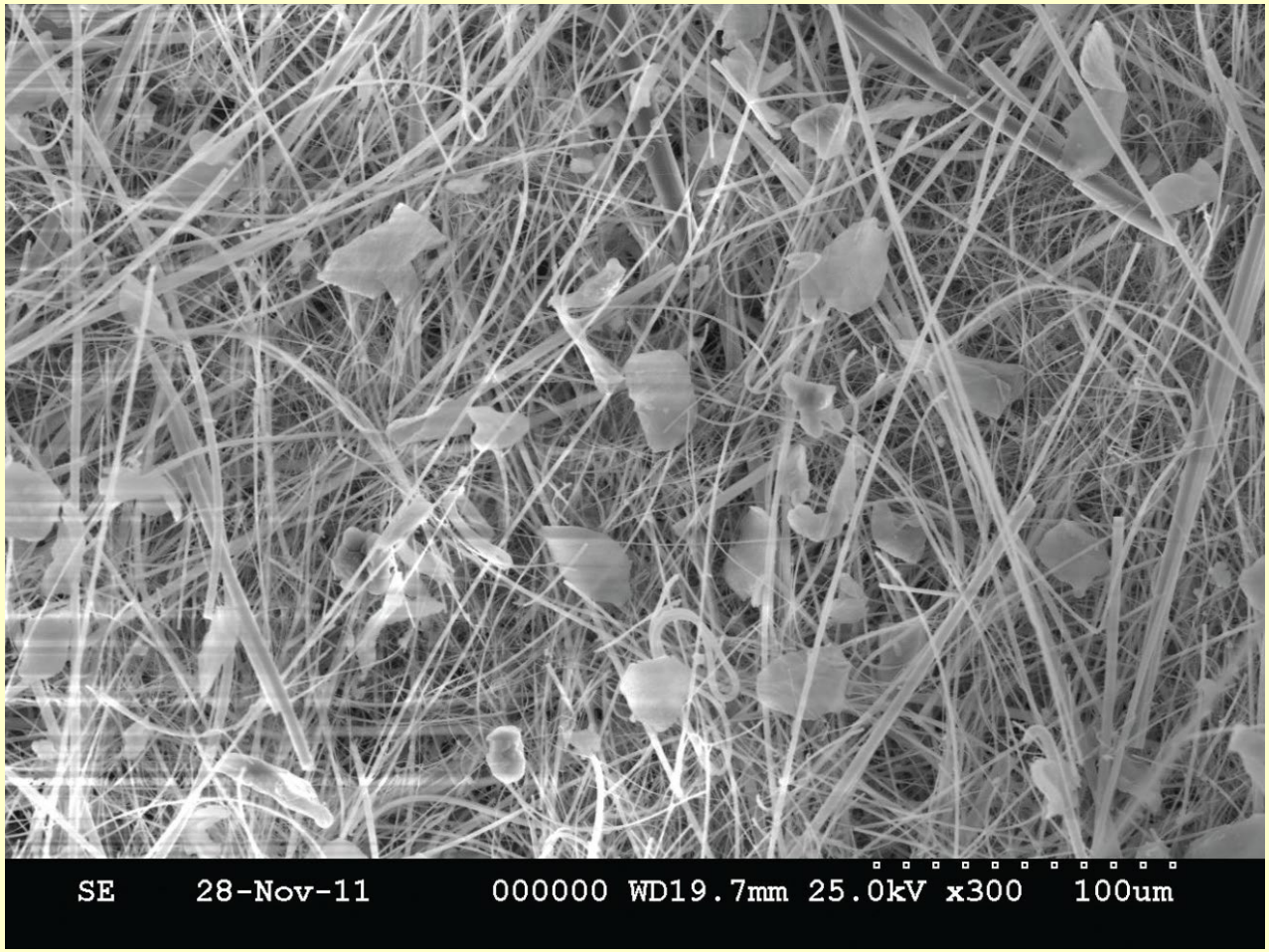
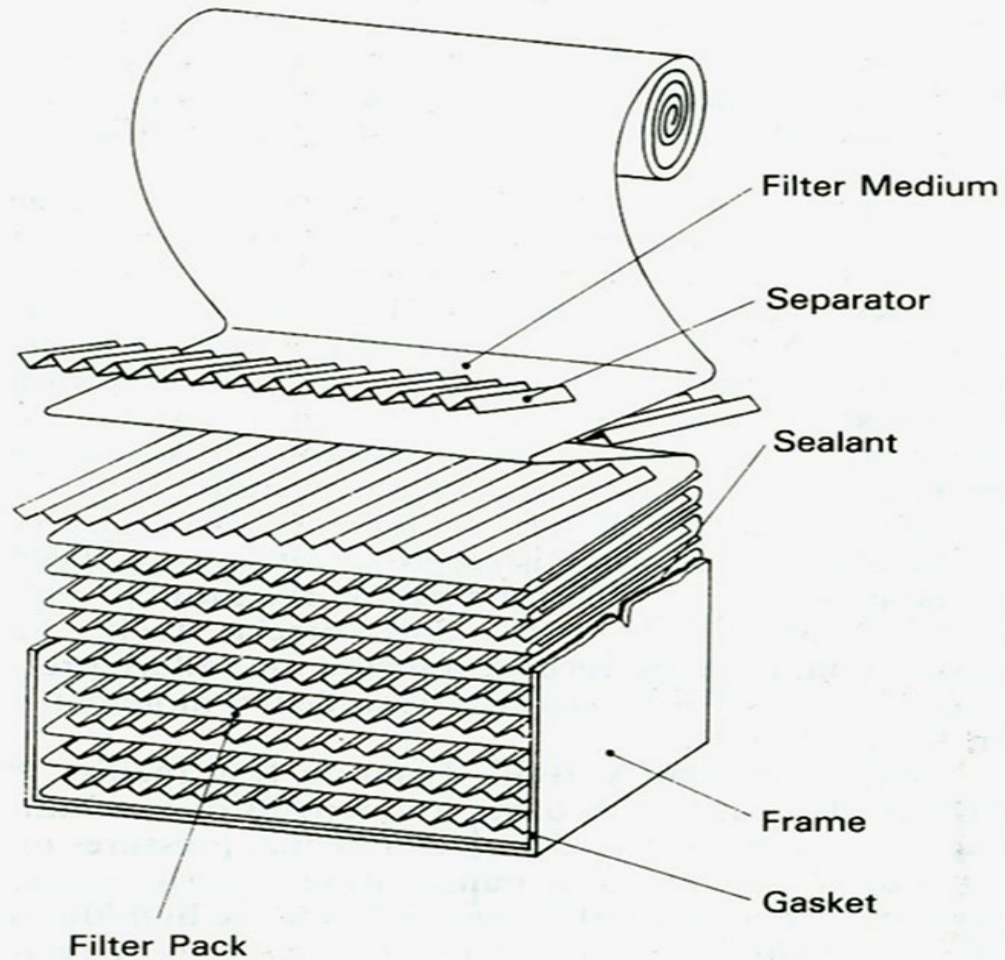
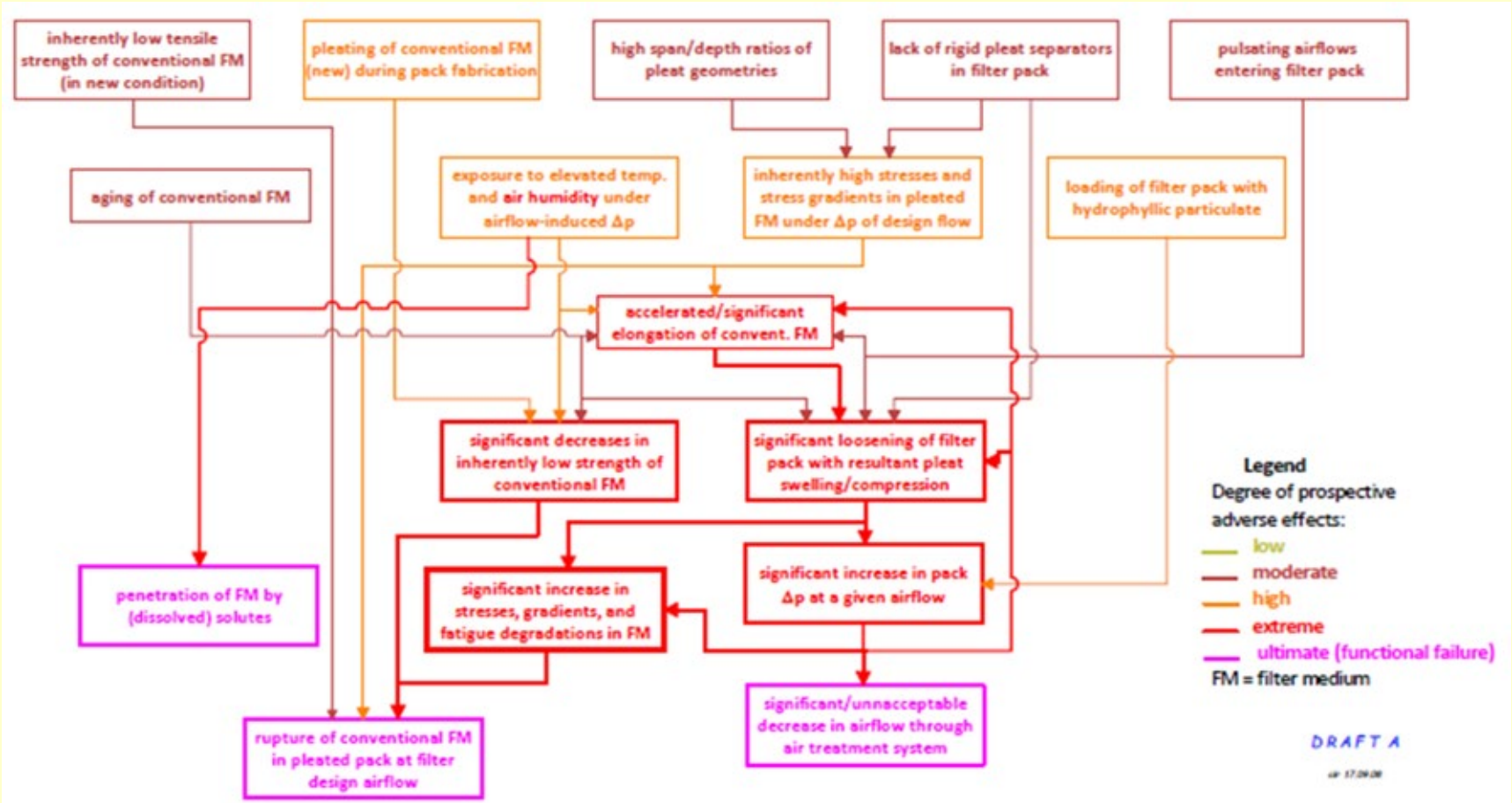
Design Material, Unreinforced



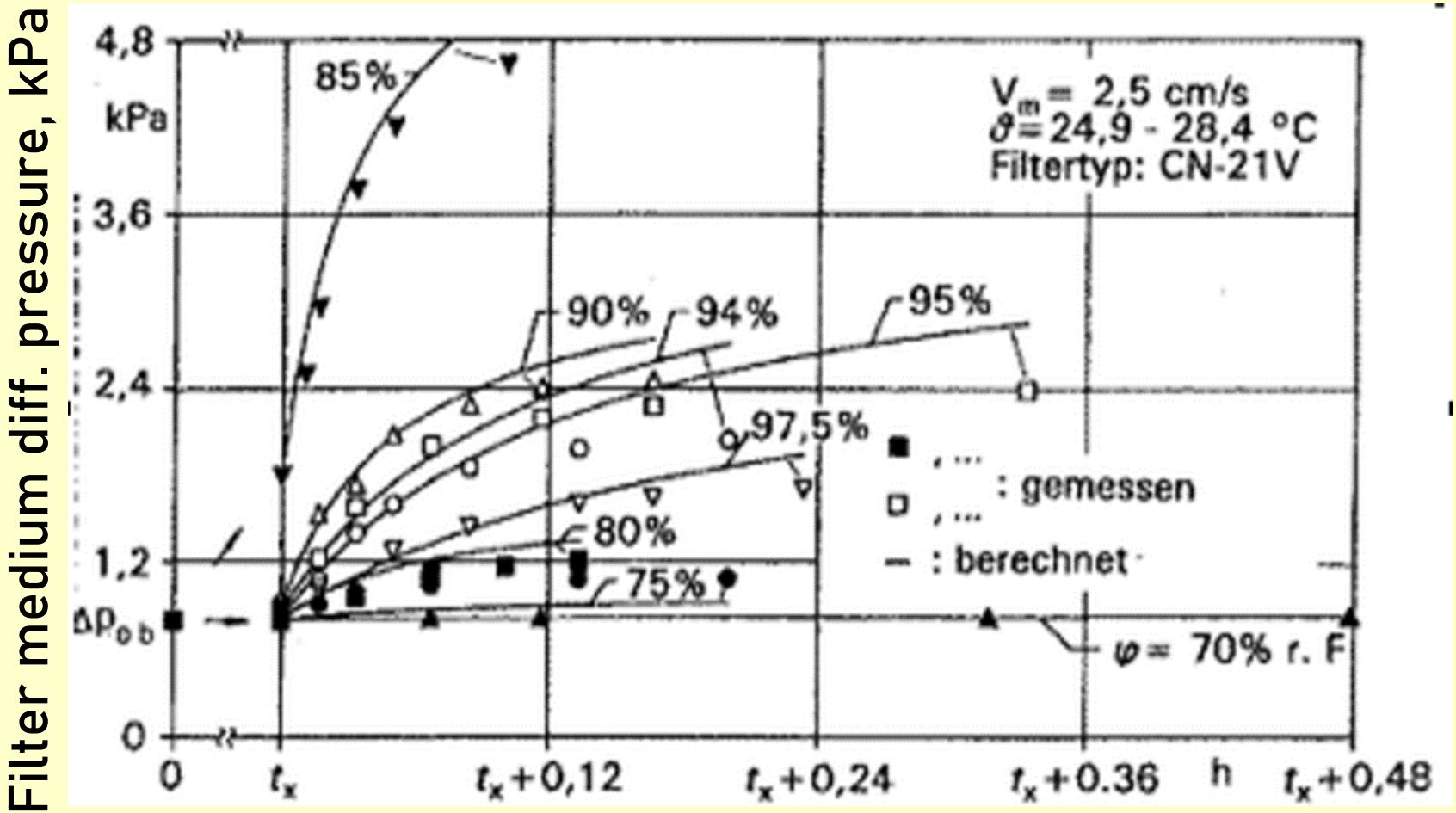
Deep-Pleat Filter Pack



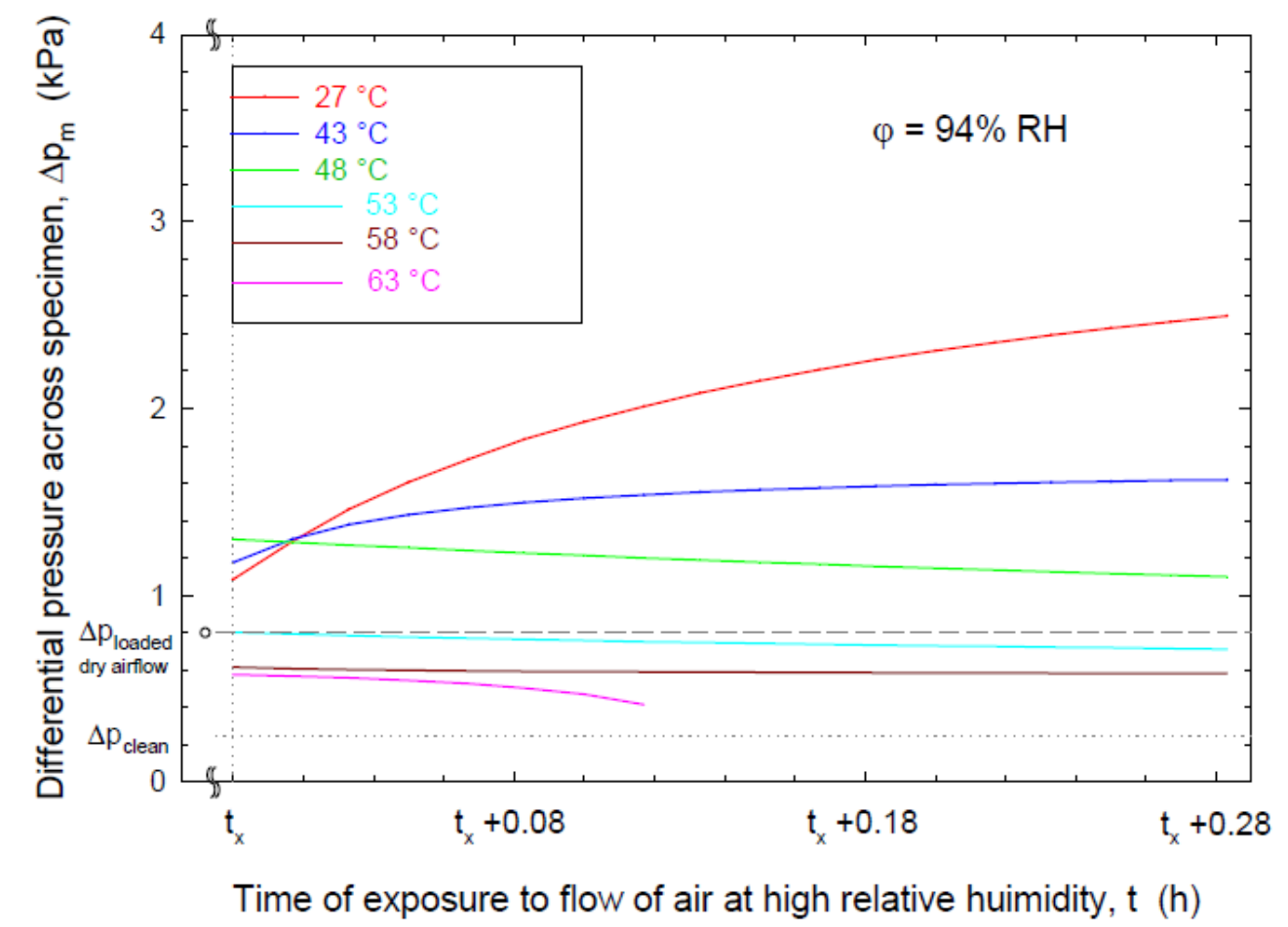
Root Causes of Filter Failure



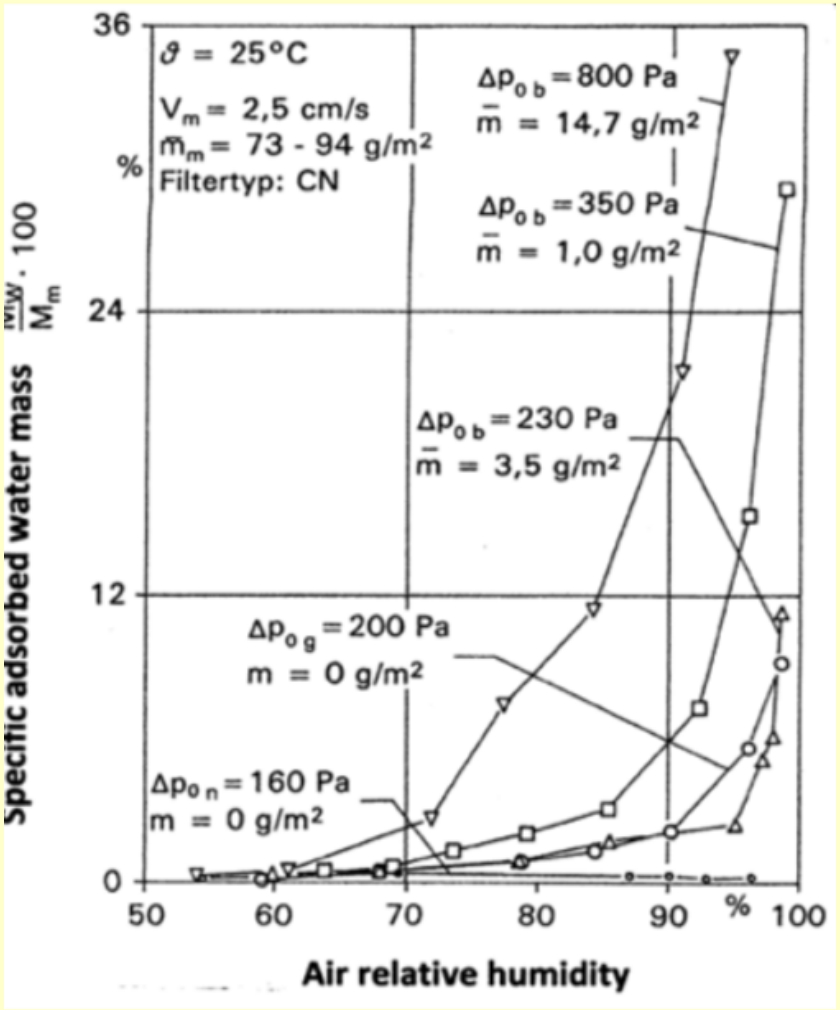
Curves of $\Delta p_{fm} = f(\varphi, t)$



Curves of $\Delta p_{fm} = f(\theta, t)$



Filter Media Sorpt. Isotherms



Inherent Limitations of fm*

*filter medium (fm)

- fragile: weak, brittle, & anisotropic
- fatigue & moisture intolerant
- high spec. surface area – over time:

  susceptible to chemical degrad. effects
- damaged by pleating during filter manf.
- can elongate during service

Importance of Pack Rigidity

Pack loosening leads to =>

=> *filter medium* (fm) fatigue =>

=> increased *fm* stresses @ const. Δp_f =>

=> filter medium pleat⇔pleat-separator mechanical interactions =>

===> increasing risk of *filter medium* ***rupture*** in service

Recognize as Struct. Element?

- ductwork √
- filter housings √
- filter pleat separators (Al.) √
- filter cases and faceguards √
- filter mounting frames √
- *Filter medium [10^{-8} m]* (X) *No*
- *HEPA filters/filter packs [10^{1}] m* (X) *No*
- moisture separators √

h-s Filter Pack Characteristics

- filter medium strength: 10x – 20x higher
- potential filter proof strengths:
  15x – 60x higher for deep-pleat designs
- filter pack: significantly tighter
- reliable pack robustness: throughout filter service life

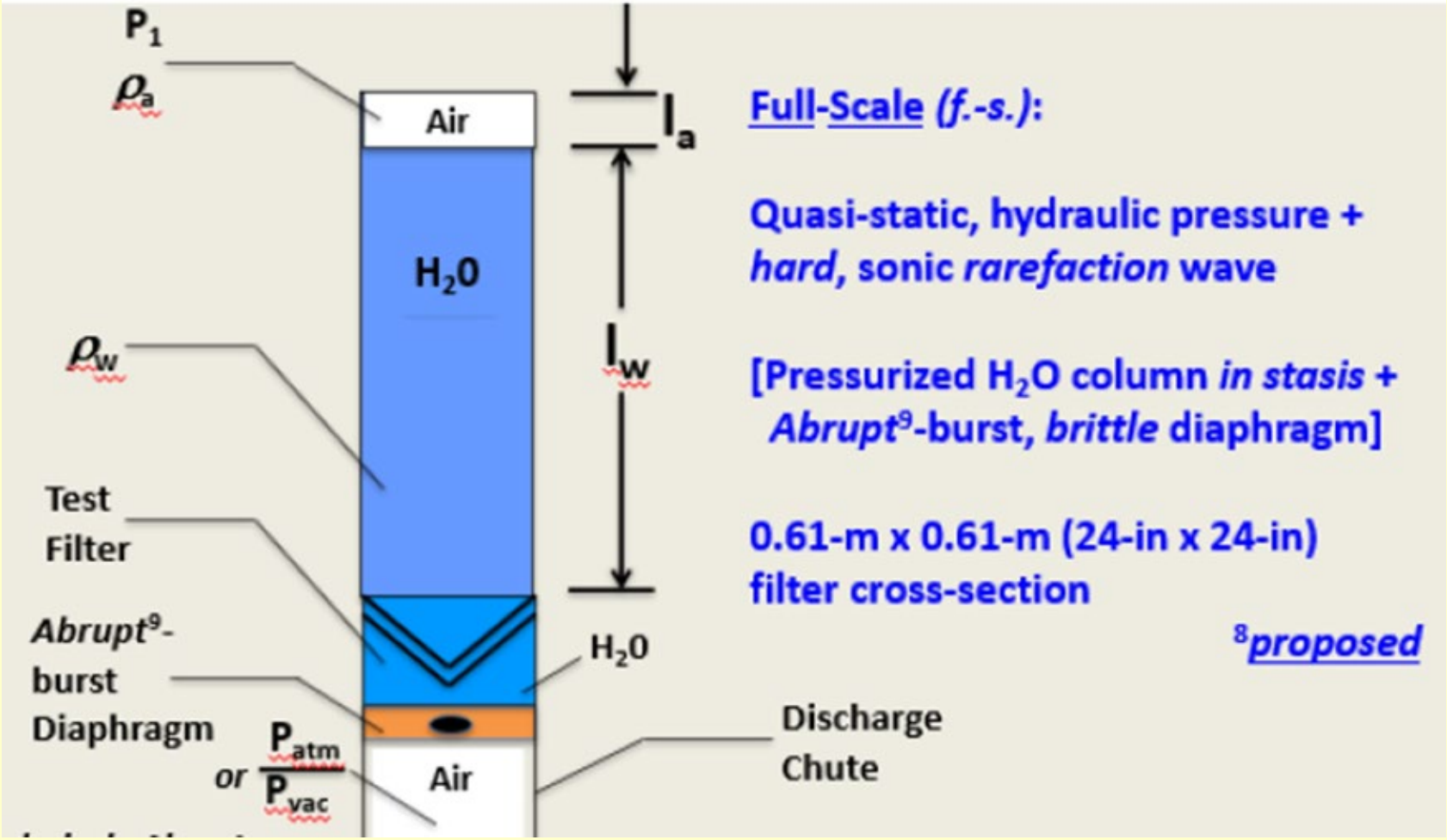
Advantages of h-s Filter Packs

- ***can*** be treated as structural elements
- can increase levels of filter reliability
- can allow calculation of meaningful safety factors for filters in service
- can enhance filter safety margins in high-risk applications
- can lower filter life-cycle costs

Filter Adoption Prerequisites

- recognition/treatment of h-s filter packs as structural elements √ √ / √ √
- stringent performance specifications and test rigs for qualification √ √
- administrative limits on adverse filter service conditions and age (X) No & / ***differentiation*** from conv. designs (X) No
- regulatory mandates √ √

Impulse Pressure Test Stand



Full-Scale *(f.-s.)*:

Quasi-static, hydraulic pressure + *hard*, sonic *rarefaction* wave

[Pressurized H_2O column *in stasis* + *Abrupt*[9]-burst, *brittle* diaphragm]

0.61-m x 0.61-m (24-in x 24-in) filter cross-section

[8]*proposed*

h-s Filter Pack – post test

'Post test with *propelled/falling*-water-column, in f-s. rig[3]:
upstream side [peak Δp_f >170 kPa (25 psid)]

[3]prototypical

Key Summary Points

- nonreinforced filter media are the *Achilles heel* of conventional HEPA filter pack designs, due to: fragility & strength degradations from pleating, fatigue, moisture exposure, and aging
- selection of: a reinforced filter medium and other pack design options allow h-s filter packs to be treated as structural components in ACS's

Conclusions

High-strength filter pack designs:

- **involve deselection of non-reinforced glass-fiber HEPA filter media as a design material (dm) option**
- **realistically address the strength limitations of nonreinforced media**
- **interface a *10^{-8}-m* dm to ones of *10^{1}* m**
- **can provide many advantages to users**