Engineered Nanoparticles and Respiratory Protection

Erik Johnson

3M Company

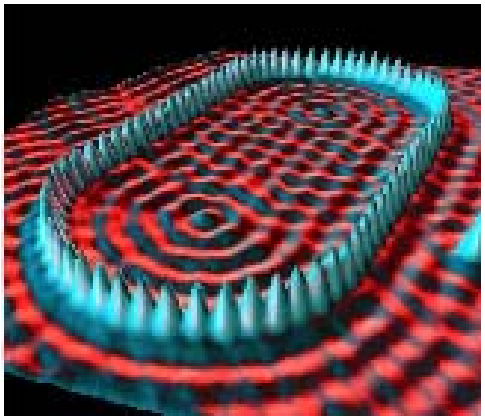
OHSIG, New Zealand
September 11, 2008

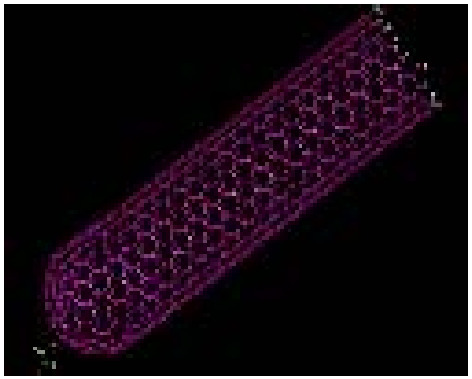
Agenda

- What are engineered nanoparticles?
- Industrial hygiene methods for sampling and limiting worker exposure
- Respirator selection and nanoparticle filtration
- Facial fit
- Conclusions

Engineered Nanomaterials

- Intentionally designed structures with size <100 nanometers
- High surface area to mass ratio
- Novel properties (strength, reactivity, etc.) different from the parent material
  - Quantum dots
  - Carbon nanotubes
  - Etc.





General Applications

- **Currently available commercially**
  - Computer chips/Information storage
  - Sunscreens and cosmetics
  - Composites
  - Clays
  - Coatings and surfaces
  - Tougher and harder cutting tools
- **Short term (commercialized in 5-10 years)**
  - Paints
  - Remediation
  - Fuel cells
  - Screen and monitor displays
  - Batteries
  - Fuel additives
  - Catalysts

Unintentionally Produced or Released Nanosized Particles

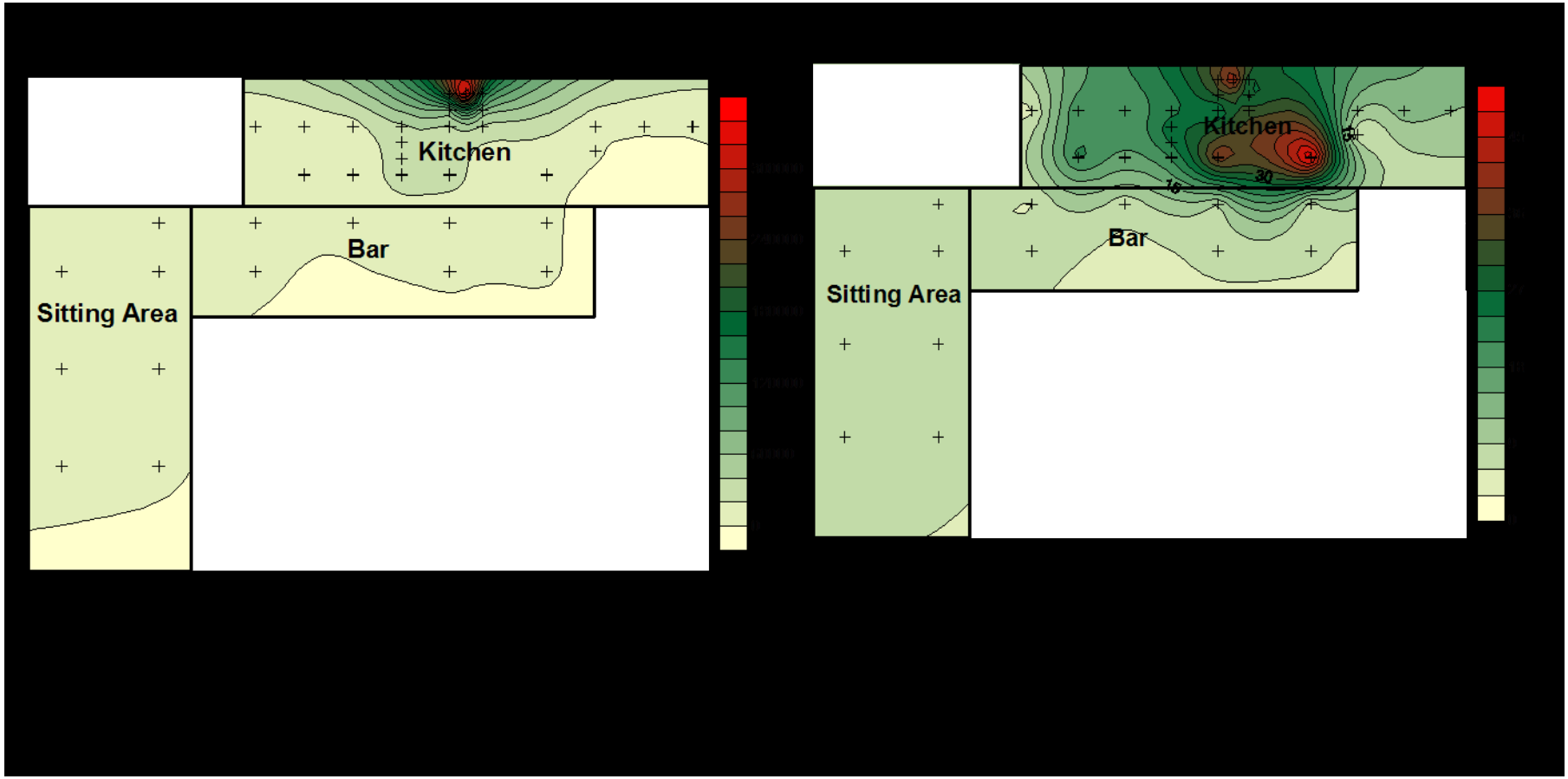
- Welding fumes
- Fumed metal oxides
- Diesel particles
- Carbon black production
- Metalworking fluid aerosol
- Combustion sources (traffic, forest fires, gas stove)
- Atmospheric gas to particle conversion
- Evaporation of volatile materials leaving submicrometer particles
- Other

Industrial Hygiene Sampling

- Most occupational exposure limits for particles are based on mass
- Nanoparticle concentration might be small in terms of mass, but quite large based on surface area or number
- Industrial hygienists need personal sampling method that collects the most appropriate, biologically relevant fraction
- No exposure limits yet specifically for engineered nanoparticles
  - Need to do more toxicology studies

University of Minnesota (Ramachandran and Park)

Number concentration maps



Surface area concentration map

General Industrial Hygiene Practice

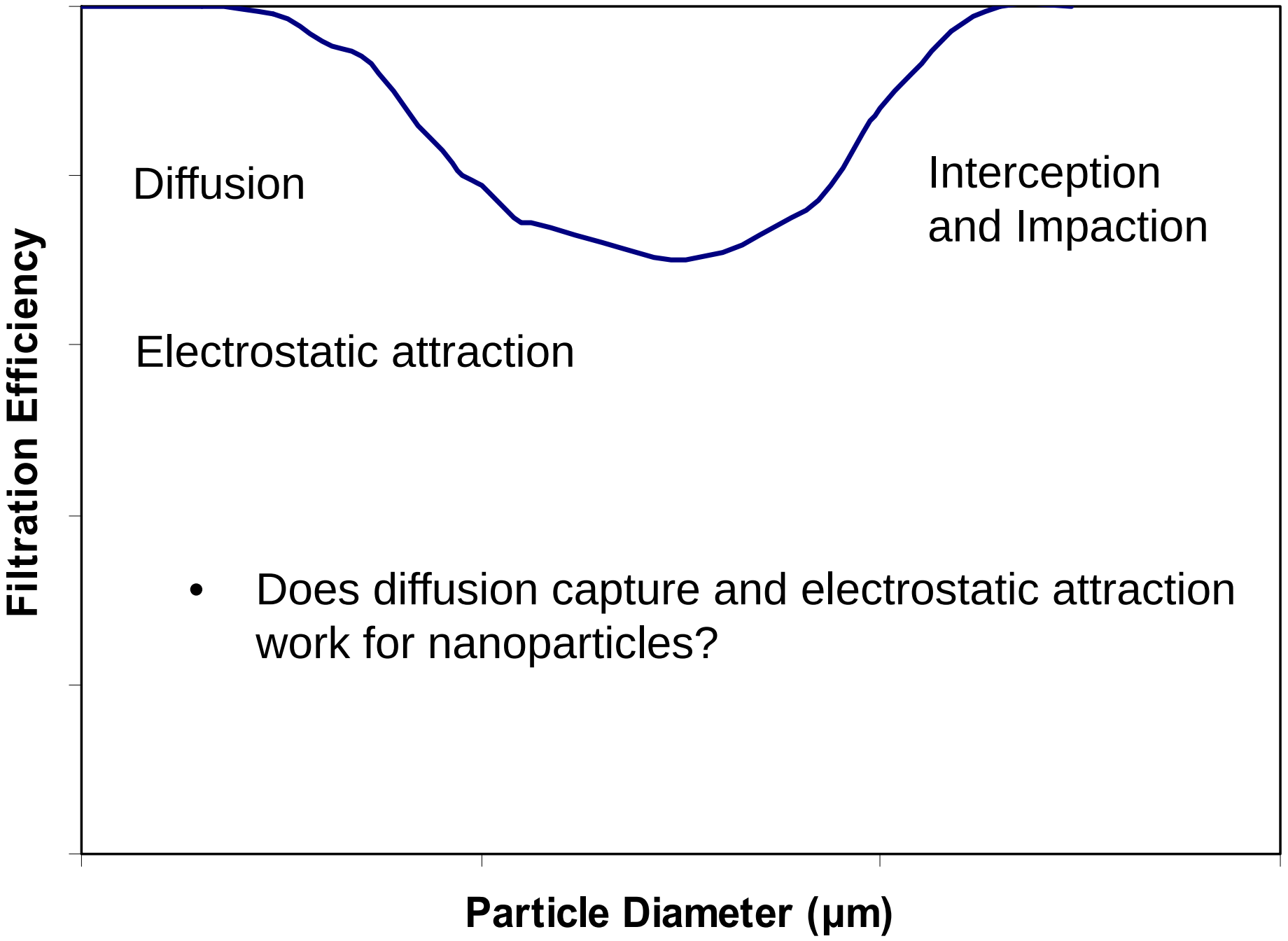
- Compare worker exposure to exposure limits
  - If above exposure limit, need to reduce exposure
  - No published exposure limits specifically for engineered nanoparticles
- Control Hierarchy
  - Substitution of a safer material
  - Engineering (enclosure, local exhaust ventilation)
  - Administrative controls (limit exposure time)
  - Personal protective equipment (respirators)
    - PPE is only to be used when other methods are not adequate, not feasible, or while they are being implemented

Respirators for Use Against Engineered Nanoparticles

- Filtering facepiece respirator
- Reusable facepiece with particulate filters
- Powered air purifying respirator (PAPR) with particulate filters

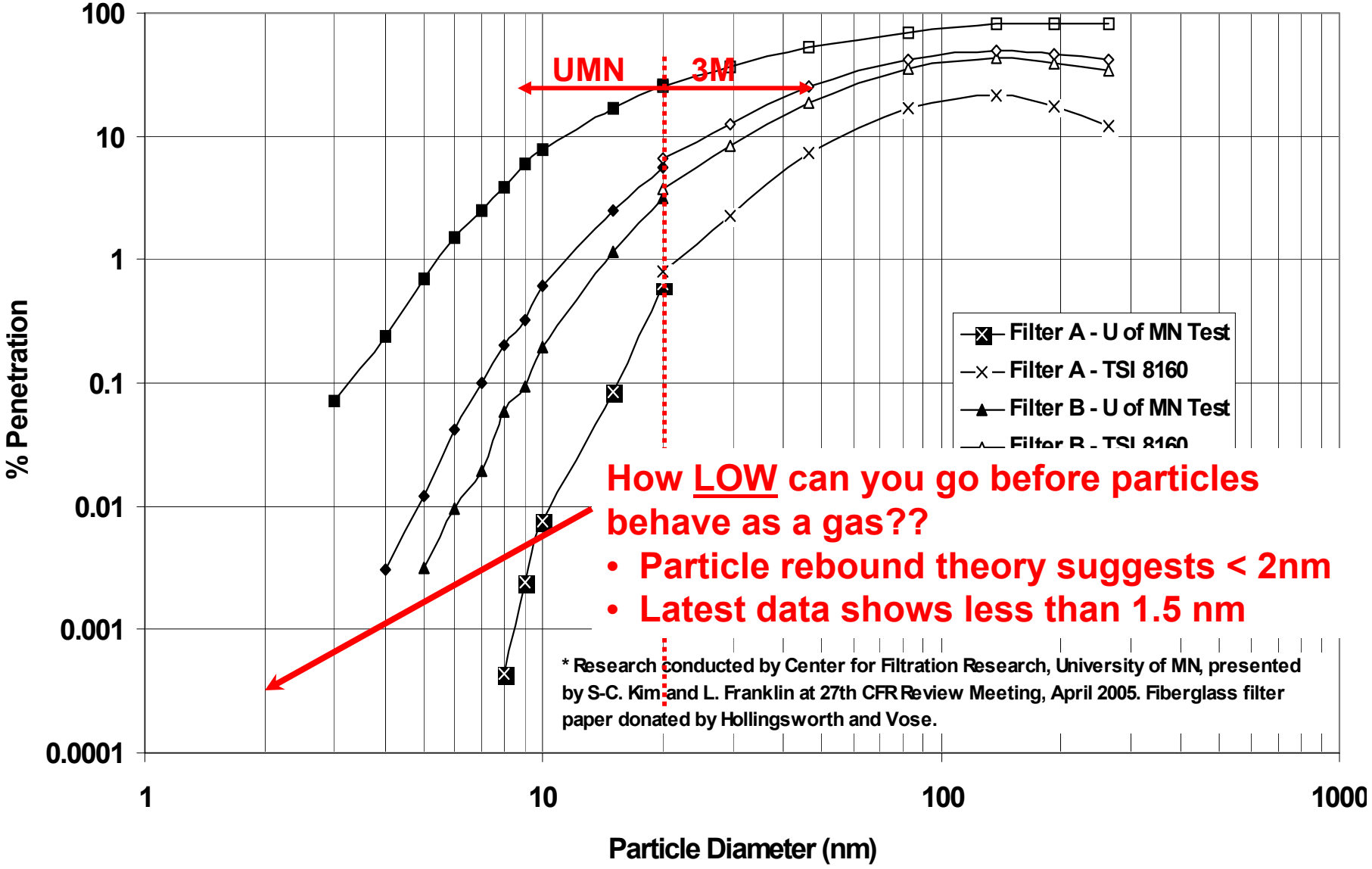
  (Suggest P2 or P3 filters similar to logic for thermally generated particles)

- Supplied air respirator--air supplied via compressor or remote bottle(s)
- Self contained breathing apparatus (SCBA)



- Does diffusion capture and electrostatic attraction work for nanoparticles?

Nano-sized Particle Percent Penetration Comparison for Four Fiberglass Filter Papers: U of MN Test (Silver Particles) and 3M Company TSI 8160 (NaCl Particles)* at 10 cm/s

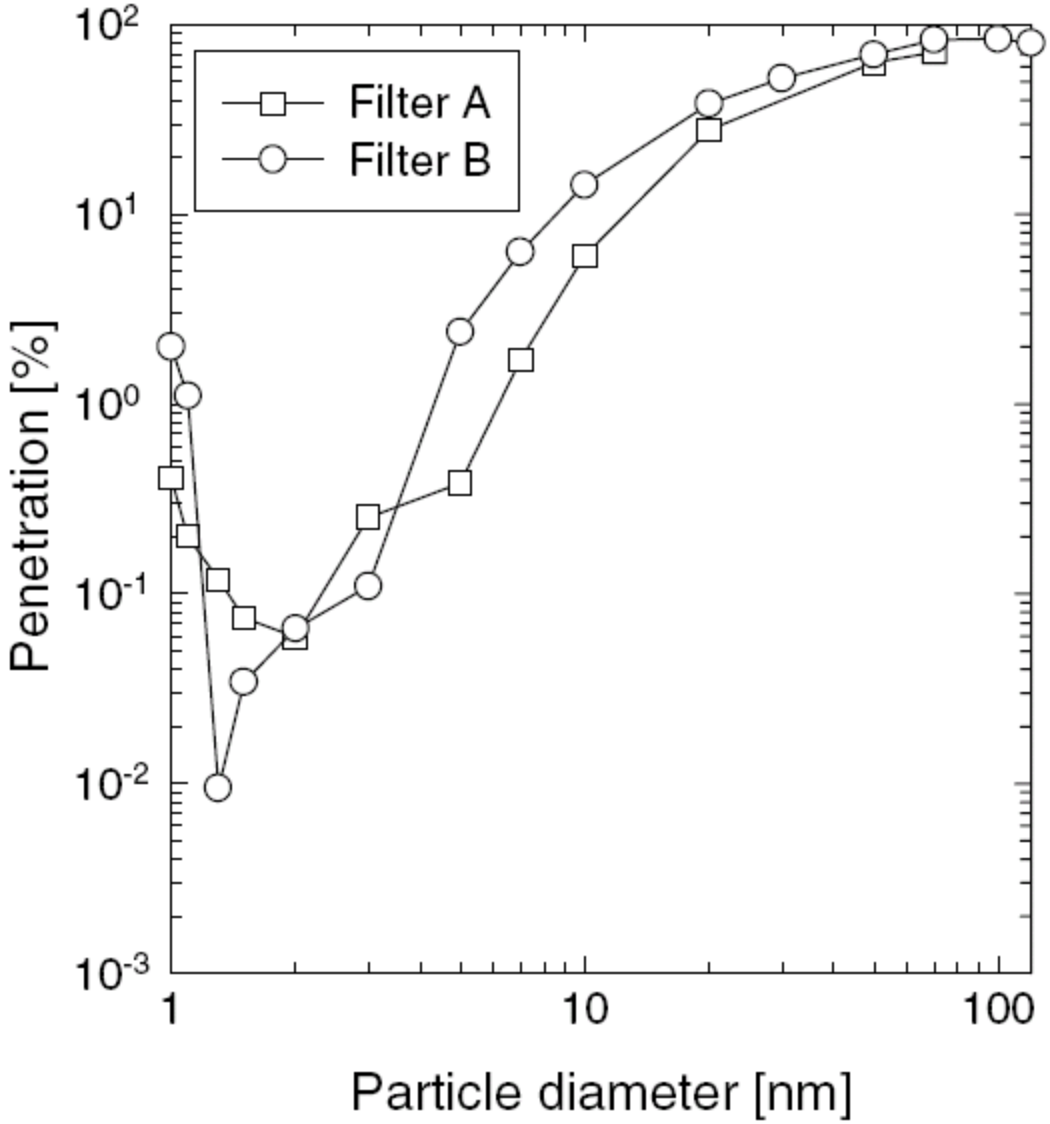


* Research conducted by Center for Filtration Research, University of MN, presented by S-C. Kim and L. Franklin at 27th CFR Review Meeting, April 2005. Fiberglass filter paper donated by Hollingsworth and Vose.

Kim, C.S. et al. "Filtration efficiency of a fibrous filter for nanoparticles" (2006), Journal of Nanoparticle Research v 8 n2, p. 215-221

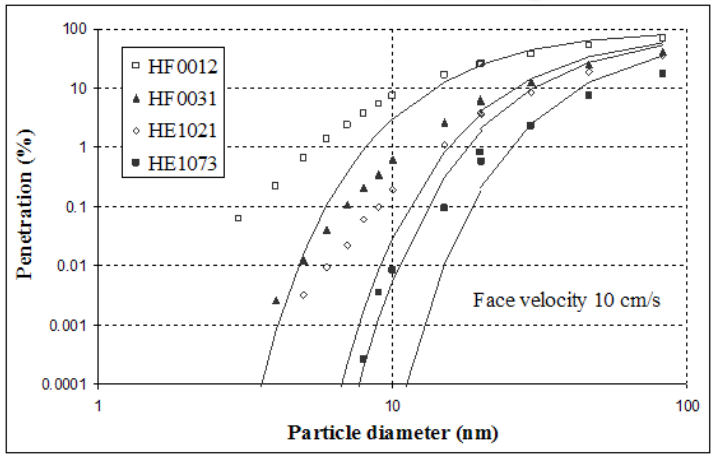
Note: this is at the lowest limits of particle detection. In order to measure any penetration in these lower limits, the filter must be of very low efficiency (penetration >80% at 100 nm).

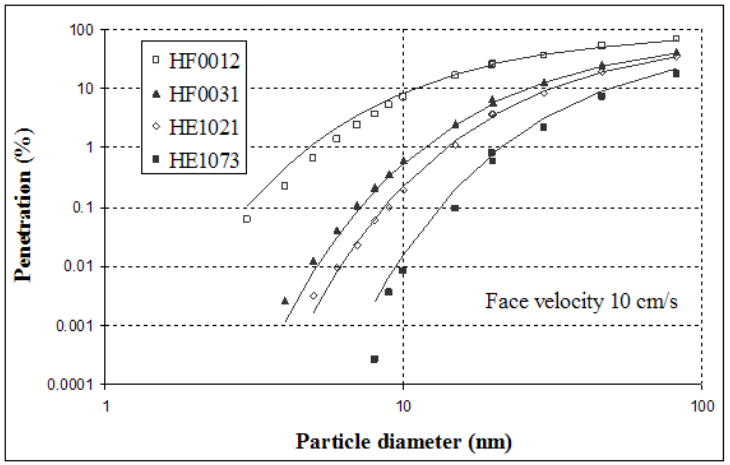
Also, particles <2 nm would agglomerate very quickly.



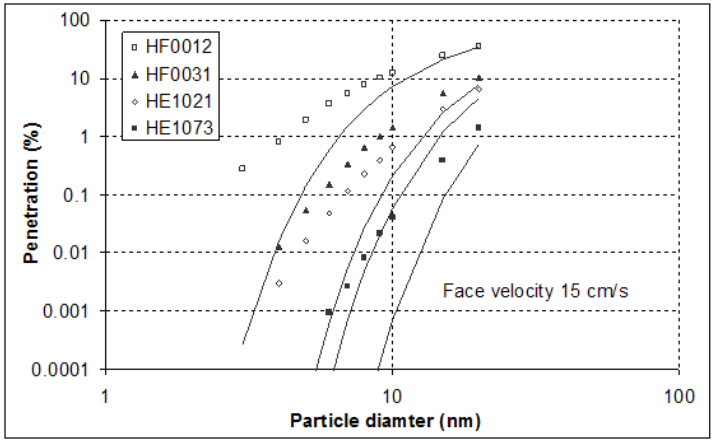
Comparison with Filter Penetration Theory (Jing Wang, U of MN)

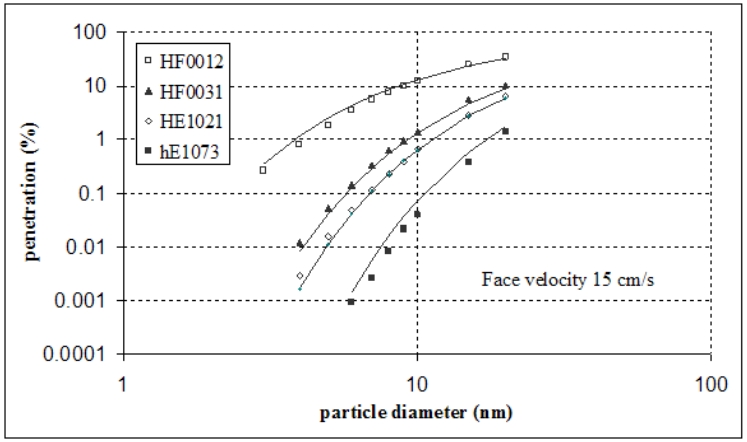
U_0=10 cm/s





U_0=15 cm/s

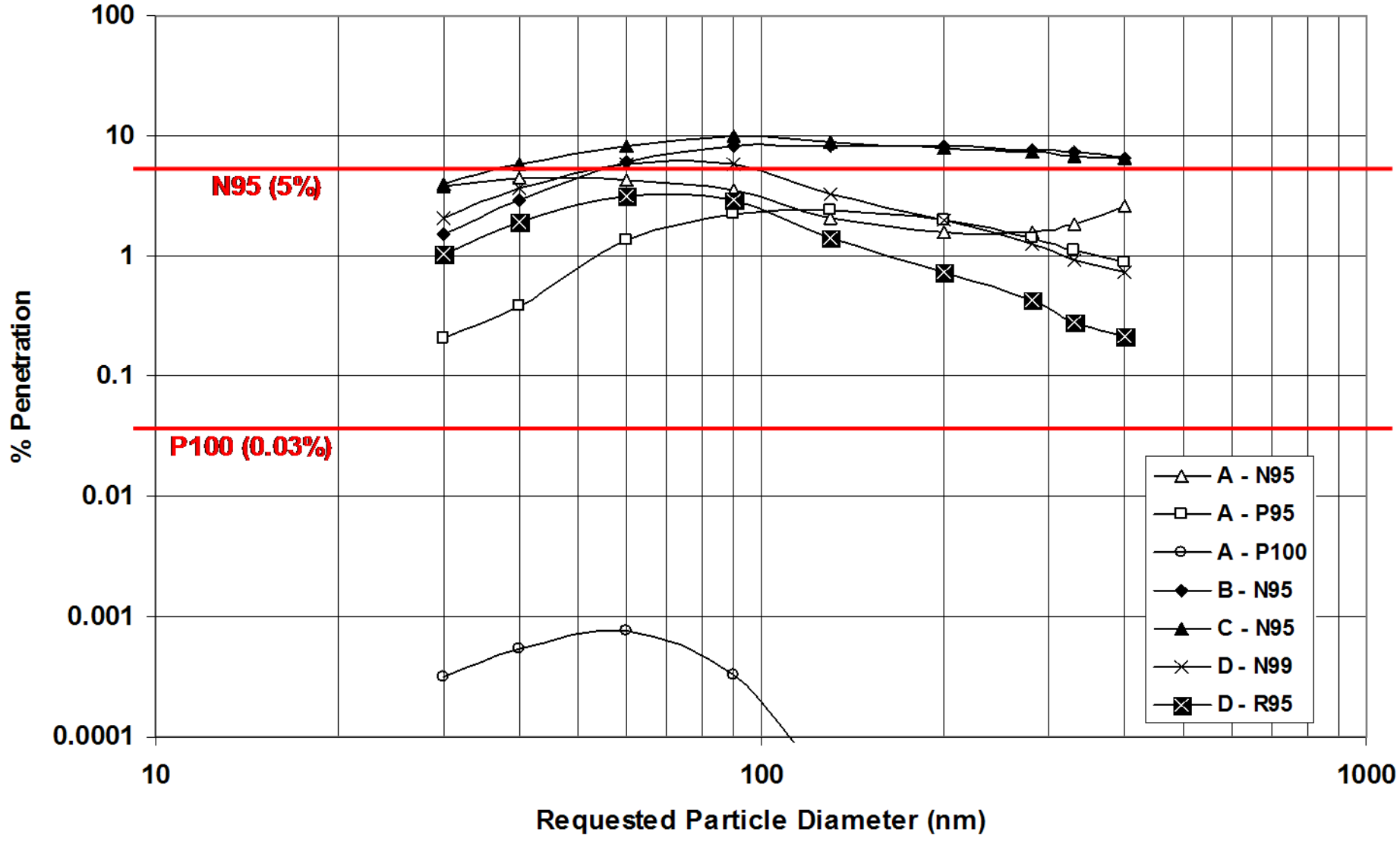




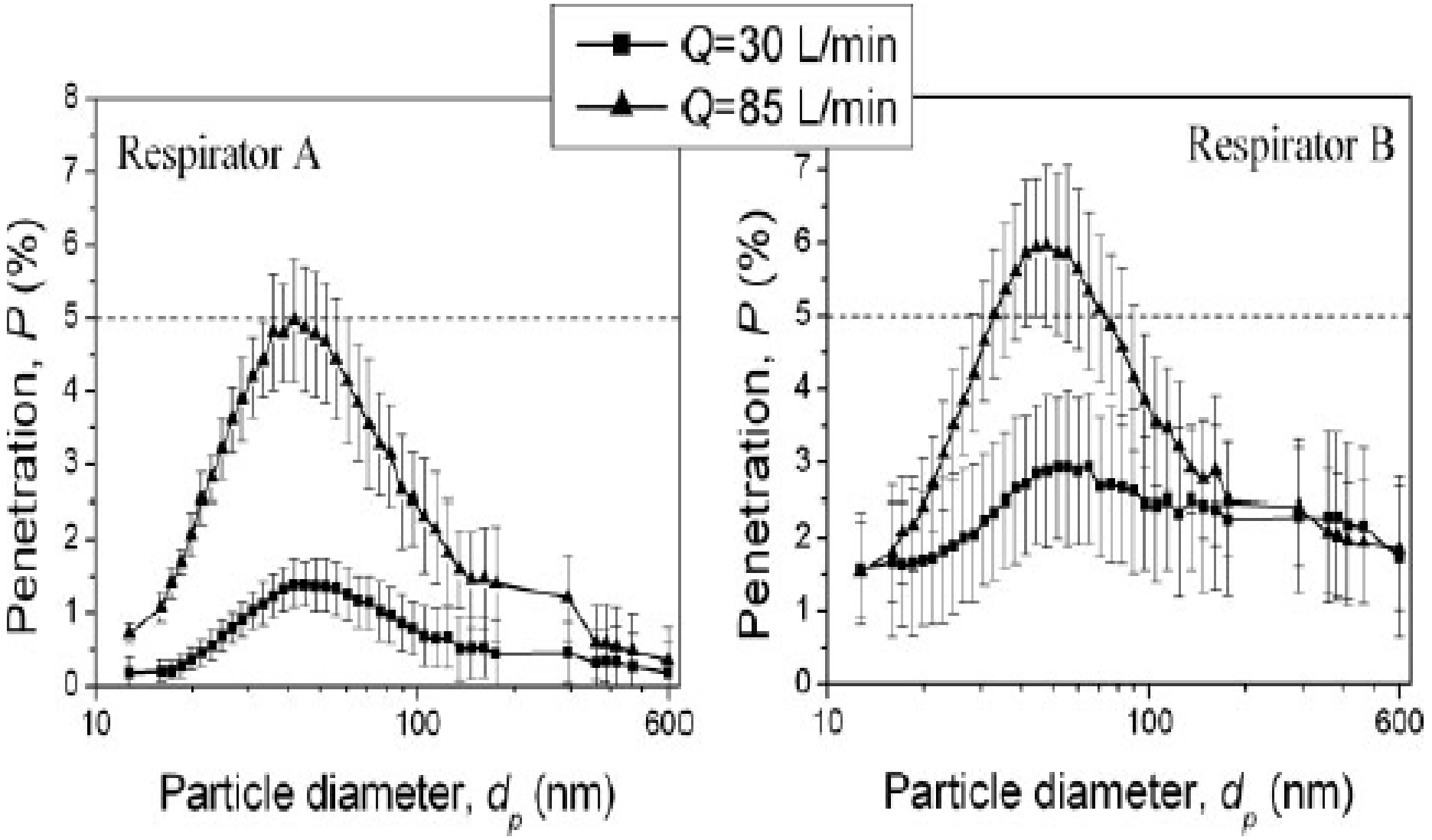
Symbols: experimental data.
Lines: penetration calculated using Hind's equation $E = 2Pe^{-2/3}$

Symbols: experimental data.
Lines: penetration calculated using $E = 0.84Pe^{-0.43}$

NIOSH Testing at 85 lpm (equiv.) on the TSI 8160 for Respirators and Cartridges from Various Manufacturers (Martin and Moyer (2000) and Moyer (2002))

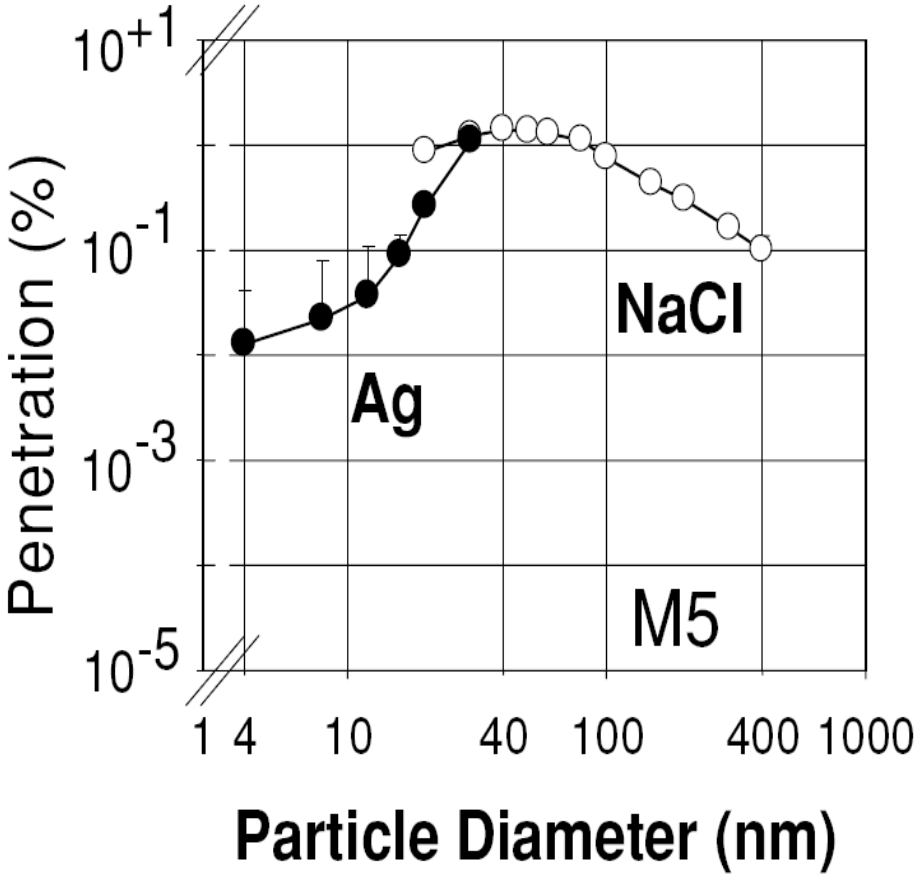


Balazy et al. “Manikin-Based Performance of N95 Filtering-Facepiece Respirators Challenged with Nanoparticles” *Ann. Occup. Hyg.* 50(3), 2006.

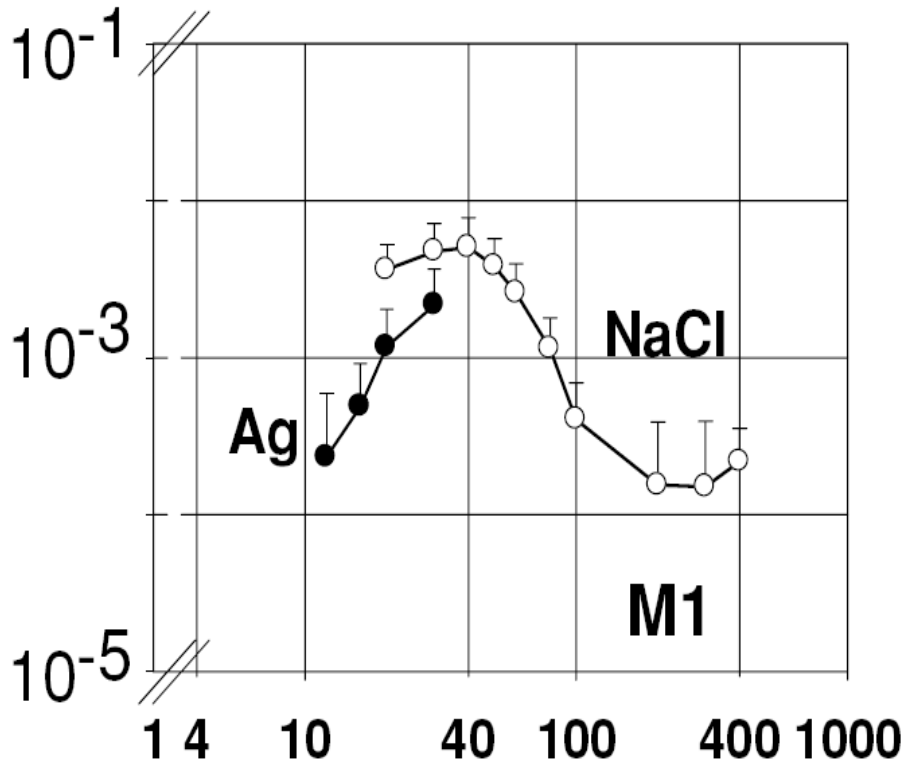


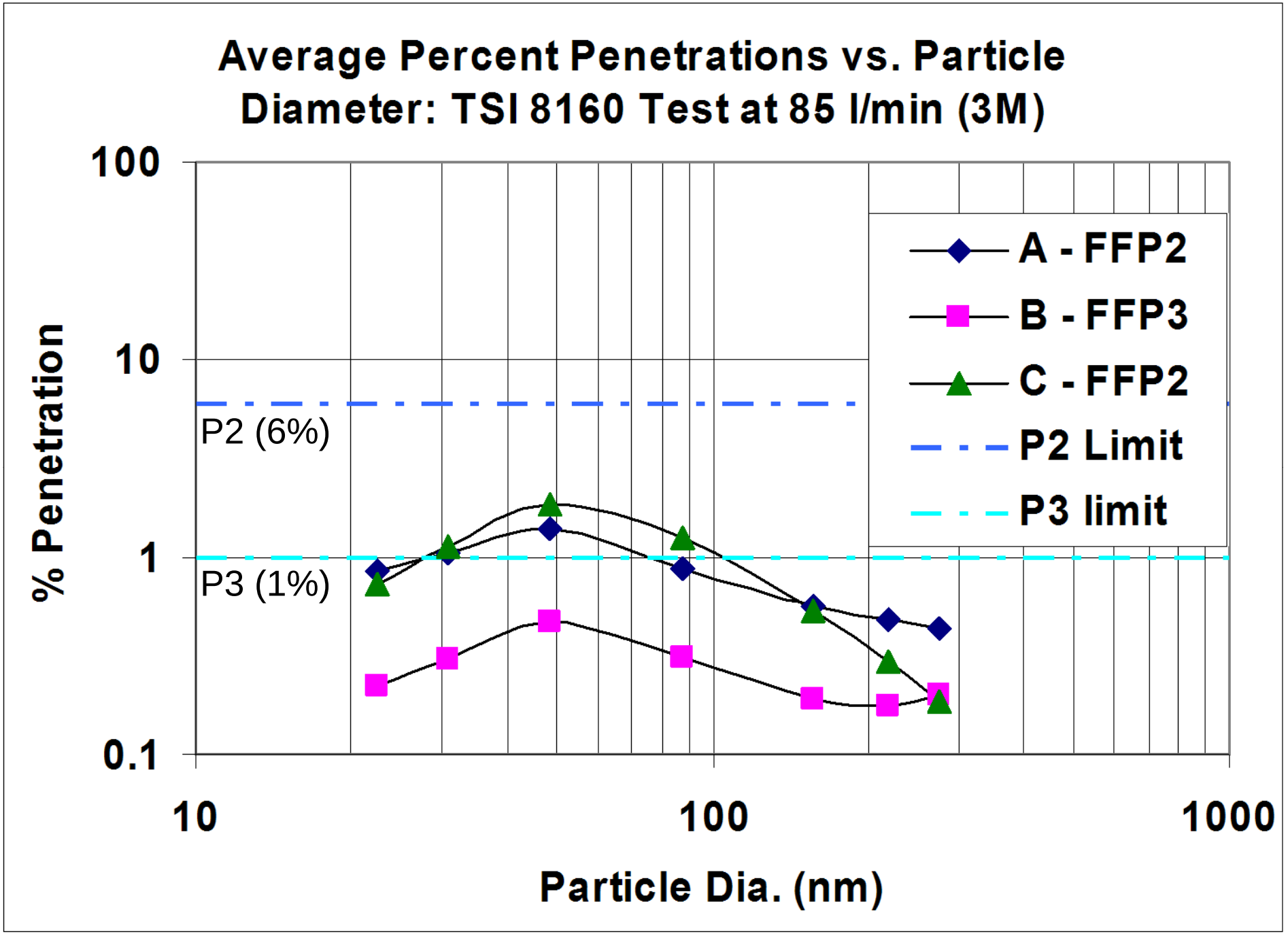
Rengasamy et al. “Filtration Performance of NIOSH-Approved N95 and P100 Fitlering Facepiece Respirators Against 4 to 30 Nanometer-Size Nanoparticles” *J. Occup. Env. Hyg.* 5(9): 2008.

N95 Respirator



P100 Respirator




Average Percent Penetrations vs. Particle Diameter: TSI 8160 Test at 85 l/min (3M)
100
10
1
0.1
% Penetration
P2 (6%)
P3 (1%)
A - FFP2
B - FFP3
C - FFP2
P2 Limit
P3 limit
10
100
1000
Particle Dia. (nm)

Respirator Protection Factors

- Nominal or assigned protection factor (not filtration efficiency) helps estimate level of exposure reduction

  Exposure = outside concentration / PF

- *Assumes properly selected, fitted and worn all the time*
- See AS/NZS 1715 for more information

APF = 10

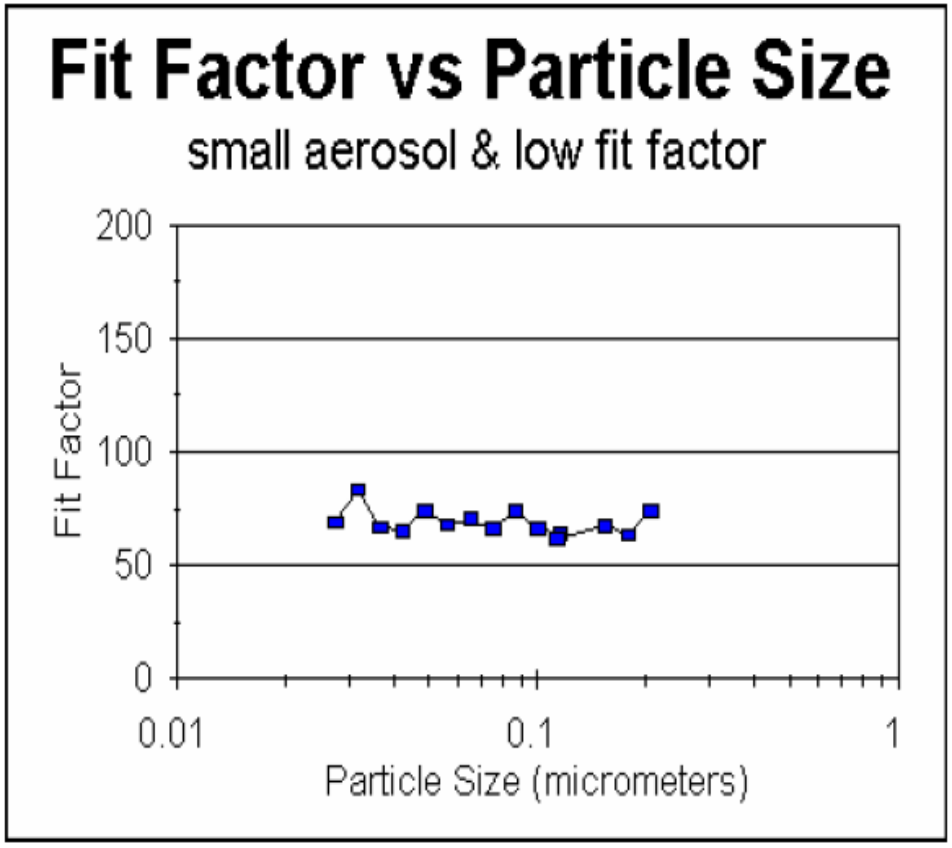
APF = 100

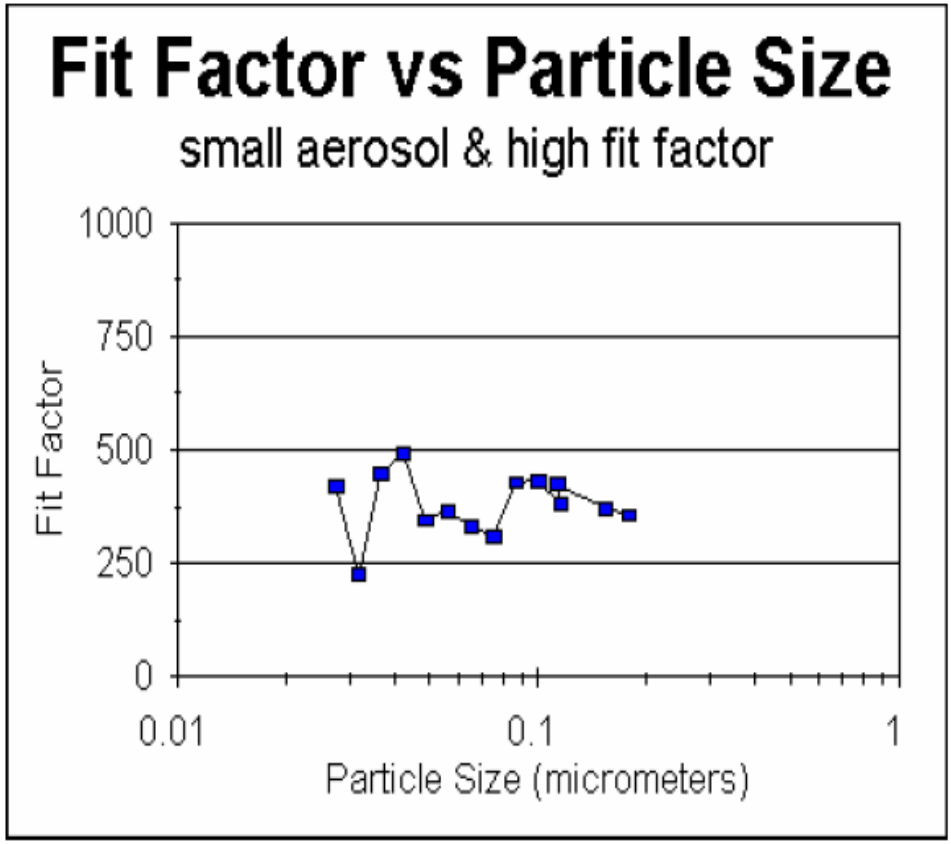
APF = 100+

Facial Fit

- Respirators commonly fit tested and used against gases and vapors (which are smaller than nanoparticles)
  - Study showed half face piece respirators fit tested using saccharin aerosol exceeded APF of 10 against styrene vapors (Weber et al. 2000)
- TSI Portacount® Pro+ measures ambient nanoparticles to determine respirator fit

“Penetration of Ambient Aerosols Through Respirator Faceseal Leaks” TSI (1995)





Summary

- Exposure limits and sampling strategies for engineered nanoparticles yet to be determined
- Engineered nanoparticles are filtered by particulate respirators
- Filtration efficiency is a function of the test method and will vary depending on particle size, flow rate and method of detection
  - Some N95 filters/respirators may have slightly >5% filter penetration at certain particle sizes AND high flow rate
  - May not be significant compared to other potential routes of exposure (face seal leakage, improper maintenance, not wearing it all the time during exposure)
- Current fit test methods are appropriate for respirators that will be used against engineered nanoparticles
- Face seal leakage appears to be independent of particle size
- Respirators may help reduce exposure if other means are not adequate or while they are being implemented