How You Test Matters:

Parameters That Affect Air Filter Testing Results

Introduction

The global health situation has led to a shortage of personal protective equipment (PPE) and has consequently motivated aerosol science researchers to testing (and publishing) on the filtration performance of various materials via a variety of instruments and methods. The results of filtration testing can vary significantly depending on how the testing is performed and published results are not always comparable. This poster summarizes the official test methods and aerosol used for respirators, medical masks, and a new category of device called barrier face coverings (BFCs), using real data to illustrate the effects of key test parameters on filtration efficiency.

Factors That Can Affect Test Results

- Particle size (distribution)
- Aerosol type (composition)
- Particle charge (neutralization)
- Face velocity
- Detector type
- Media type
- Mass loading of the media over time

Key Equations

$$Penetration = \frac{Downstream}{Upstream} = 1 - Efficiency$$

$$Face\ Velocity = \frac{Flow\ Rate}{Area}$$

Types of Devices Used in the Pandemic

Device Name	Respirators (Filtering Facepiece [e.g. N95] or Other Types of Respirators)	Barrier Face Coverings	Medical Masks
Typical Appearance	 Filtering Facepiece Respirator (e.g. N95)  Elastomeric Mask with Cartridges (e.g. P100) Or Other Respirator Type		

Relevant Standards		European: EN 143, EN 149, EN 13274-7	NIOSH (USA) 42 CFR Part 84	China GB2626	ASTM F3502	ASTM F2100
Aerosol Generator	NaCl	NaCl and Distilled Water				The ASTM F2100 standard is currently under revision (2022).
	Oil	Paraffin Oil	PAO-4 (i.e. Emery Oil) or DOP, as desired		N/A	
Filter Test Equipment		Automated Filter Tester such as Model 8130A				

Pre-pandemic: Test methods for respirators and medical masks were well-defined. There were no defined test methods for other face coverings.

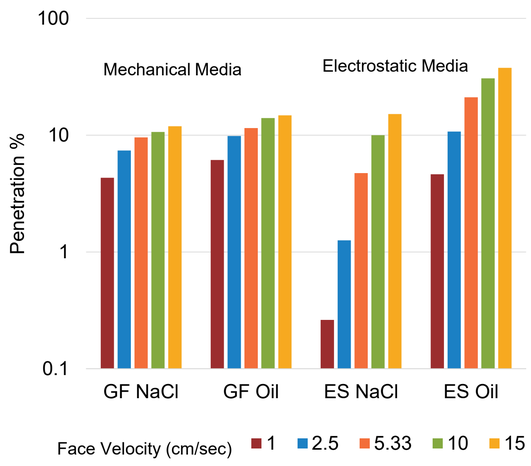
Mid-pandemic: Scarcity of PPE led to wide use of 'Barrier Face Coverings' (BFCs) by the public. A **NEW** ASTM method (F3502) was developed with a test method for BFCs.

Effect of Aerosol Type, Face Velocity and Media Type

For a given media, results are affected by aerosol type and face velocity. This is because diffusion and electrical attraction – two mechanisms by which particles are captured by filters – are velocity-dependent.

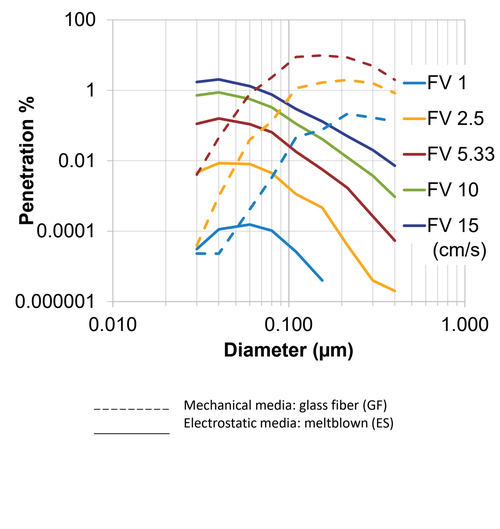
Electrostatic media shows a larger change than mechanical media and there is more charge on NaCl than oil aerosol.

Media type	Aerosol type
• Glass fiber (GF) • Electrostatic (ES)	• NaCl: salt • Oil: emery (PAO)

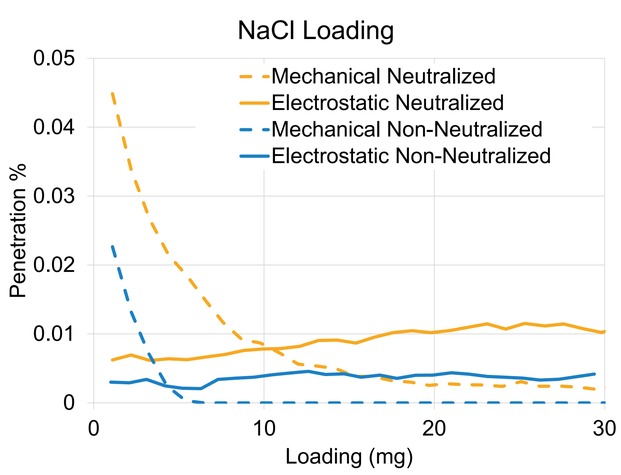


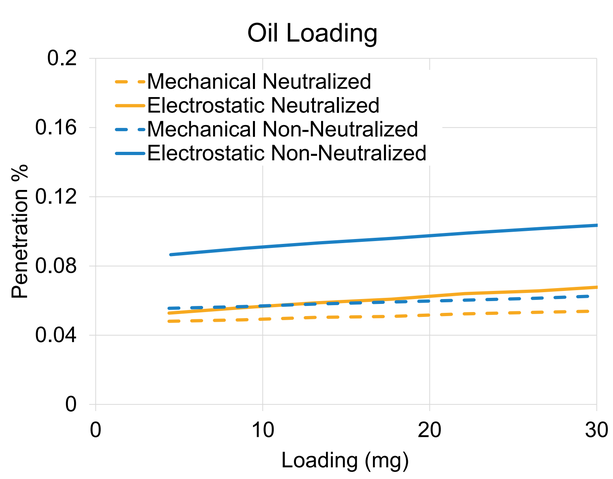
Effect of Particle Size Distribution and Face Velocity

- For a given media, particle penetration is affected by particle size and face velocity (FV).
- The electrostatic mechanism is more effective for large particles which have a higher charge; they are more easily captured by ES media, which has a smaller MPPS (Most Penetrating Particle Size).
- Small particles are efficiently removed by diffusion at low velocity. Low velocity also increases electrical capture.



Effect of Loading and Aerosol Type





Penetration can be loading-dependent and loading can increase or decrease penetration, as it affects electrostatic and mechanical media differently.

With salt aerosol:

- Loading mechanical media causes penetration to decrease due to surface area increasing (e.g., salt dendrite formation)
- Loading charged media causes the penetration to initially increase since the charged aerosol is more attracted to charged filter media, and as the charge sites are covered up.

With oil aerosol:

- As oil coats the filter fibers, causing increased inter-fiber velocity for both media types (this increases penetration).
- Oil causes more efficient shielding of charge sites on electrostatic media, resulting in larger increases in penetration.
- Oil generally has no charge when generated and neutralizing oil (adding charge) results in somewhat lower penetration.

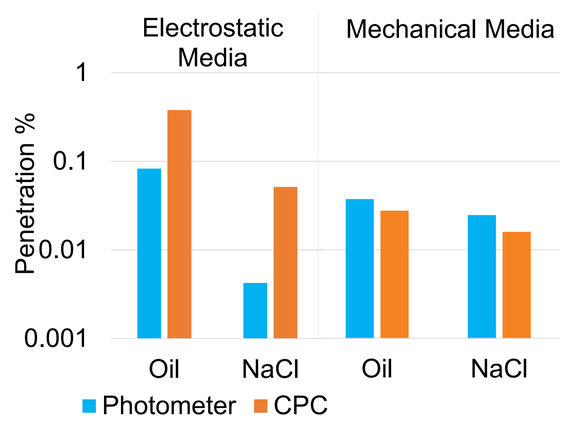
Effect of Detector Type and Media Type

Detector effects:

- Photometers measure total light scattering of all particles, collectively. Photometer **response** is very nonlinear, being proportional to $\mathbf{D_p^6}$.
- **I**n contrast, condensation Particle Counters (CPCs) count the total number of individual particles, and the response is usually not dependent on size.
- Because of these different detection techniques (and the fact that photometer response is influenced by particle size), filtration results for a given media are affected by the particle size distribution and detector response.

Media effects:

- *Electrostatic media* has a smaller MPPS than mechanical media, resulting in higher penetration with CPCs, which detect the smaller sizes. Oil has lower charge than salt, resulting in higher penetrations.
- *Mechanical media* has a flatter penetration curve, so the difference is smaller than with electrostatic media. Photometer response is biased to larger particles where the penetration is higher.



Conclusion: How You Test Matters!

- Fractional penetration tests on different filter types have different penetration curves.
- Different detection technologies (photometer vs. CPC) yield different results.
- Different aerosols give different efficiency results, as do different face velocities.
- Oil and salt load filters differently, especially for electrostatic media.
- Flow rate affects overall penetration and can shift the curve.

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