PEER REVIEWED

New developments in synthetic ASHRAE filtration media

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ABSTRACT

Over the past several years, electret charged synthetic filter media have been replacing glass filter media for ASHRAE applications. A particular concern with these new media is the phenomenon of electret decay under oily aerosol loading. This paper explores this matter and evaluates several test methodologies.

Application:

Synthetic media alternates to glass media for ASHRAE filter applications have the advantage of higher efficiency at lower resistance with higher capacity.

ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) filters come in a broad range of efficiencies. The heating and air conditioning systems of residential and small commercial buildings use elements below 25% efficiency. They are typically a flat disposable panel in a shallow cardboard, plastic, or metal frame. The medium is traditionally a resin bonded mat of coarse, continuous glass filaments. The past several years have seen the advent of coarse, electret charged synthetic fiber mats replacing this glass medium.

Higher performance elements from 60–95% efficiencies have use in the heating and air conditioning systems of large commercial buildings. Industrial applications such as hospital operating rooms, food and pharmaceutical packaging, automotive paint spray booths, gas turbines, protection, and high efficiency particulate air (HEPA) prefilters also use the higher performance units. One traditional ASHRAE medium is a lofty mat of resin bonded microfiber glass. This mat is commonly fabricated into "bag" filters. These have several pockets typically cut and stitched from mat roll goods. This type of medium may also be formed into a low pleat count box filter if it has a wire backing support.

There has been recent use of mats made with combinations of coarse and fine electret charged synthetic fibers. These synthetic ASHRAE mats find use in the bag or pocket elements and the pleated box elements. The synthetic medium offers the advantage of being sealable or weldable with heat, ultrasonics, or radio frequency energy. This is particularly useful in the manufacture of pocket elements.

Another type of medium for the 60–95% ASHRAE applications is the resin bonded, wet-laid microfiberglass paper pleated and converted into deep pleat panel filters with aluminum separators or minipleat panel filters with hot melt bead or string separators. We suspect that the next generation for this format will be a composite of electret melt blown medium with wet-laid or dry-laid synthetic pleatable layers. Synthetic media that essentially satisfy 95% ASHRAE efficiency already have use for automotive passenger compartment air filtration.

The recurring theme is clear—synthetic ASHRAE filter media are replacing glass ASHRAE filter media. The remainder of this paper will describe certain basic technical differences between the new synthetic ASHRAE media and the older glass ASHRAE media.

DUST SPOT EFFICIENCY MEASUREMENT

The ASHRAE dust spot efficiency test traditionally measures the performance of heating, ventilation, and air conditioning (HVAC) filters *(1)*. This method draws samples of air upstream and downstream of the filter element through small discs of pure white HEPA glass filter medium. If both targets use the same total sample flow, the upstream target will darken considerably more than the downstream target due to the higher number of black ambient dust particles in the upstream air. The following equation converts the measured opacity of each target into an opacity index:

$$Z = -73.27 \ln(1 - Y/66.07) \quad (1)$$

where

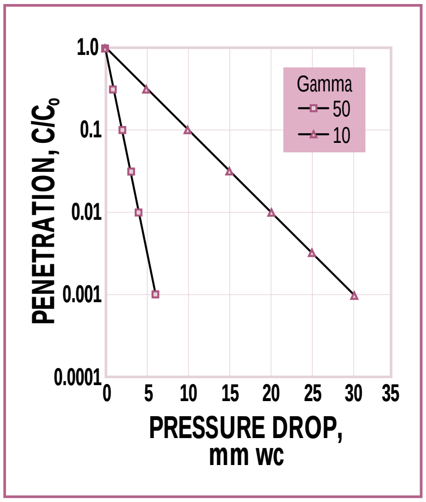
Y = measured opacity
Z = opacity index.

Penetration is the ratio of the opacity index of the downstream target to the opacity index of the upstream target expressed as a percentage. Efficiency is 100 minus the penetration:

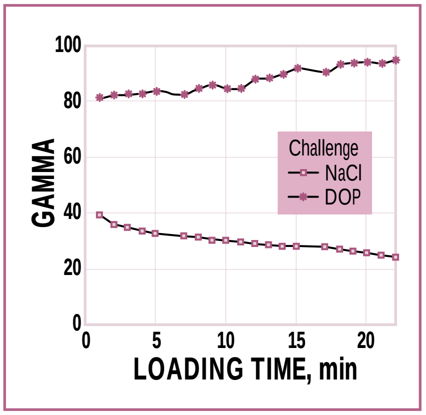
$$E = 100 - P = 100(1 - Z_d/Z_u) \quad (2)$$

where

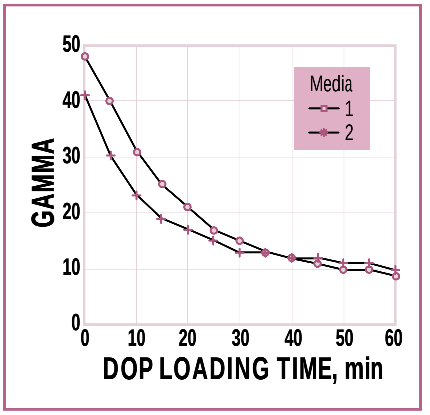
E = efficiency
P = penetration
Z_d = downstream opacity index
Z_u = upstream opacity index.



1. Penetration vs. resistance



2. Changes in gamma with challenge loading



3. Effect of DOP loading on synthetic ASHRAE performance

Media	Gamma
Glass ASHRAE	7–10
Glass HEPA	10–13
Uncharged melt blown	7–10
Charged melt blown	30–35
Improved charged melt blown	45–50

I. Typical gamma values

The dust spot efficiency test is far from ideal. This is partly due to variation in the size of the dark ambient dust particles at different locations. ASHRAE is revising the test method to include the concept of fractional efficiency over a range of particle sizes measured with a laser particle counter. In our development work, we have been using fractional efficiency measured by laser counter with ambient dust rather than the dust spot efficiency. We also rely on dioctyl phthalate (DOP) penetration tested with a commercial tester measuring 0.3 µm particles and the NaCl penetration tested with a commercial tester measuring 0.5 µm particles *(2)*. It is usually possible to relate monotonically the various fractional efficiencies and penetrations to each other but not to the dust spot efficiency, because it varies with ambient conditions.

PENETRATION, RESISTANCE, AND GAMMA

Although it is common to discuss the efficiency of the media, it makes more sense mathematically to discuss the penetration. Penetration is the ratio of downstream particle concentration to upstream particle concentration. Resistance is the pressure drop across the filter sheet or element. When testing flat sheets of media at a given face velocity, the penetration is obviously multiplicative, and the resistance is additive. The cumulative penetration of two sheets therefore will be the product of the individual penetrations, and the resistance of two sheets will be the sum of the individual resistances. **Figure 1** shows this graphically.

Figure 1 is a semilogarithmic graph of the penetration and resistance for multiple layers of the same sheet. The following equation defines the slope of such a curve:

$$\gamma = -100 \log(C/C_0)/\Delta P \qquad (3)$$

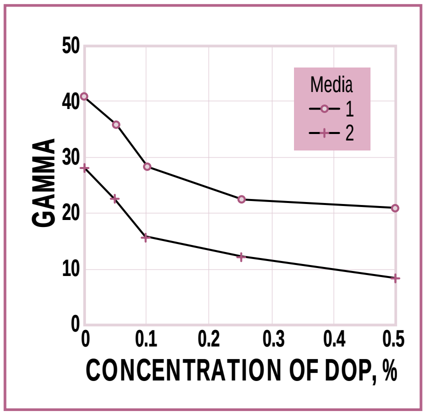
where

γ = slope of curve
C = downstream concentration
C_0 = upstream concentration
ΔP = resistance.

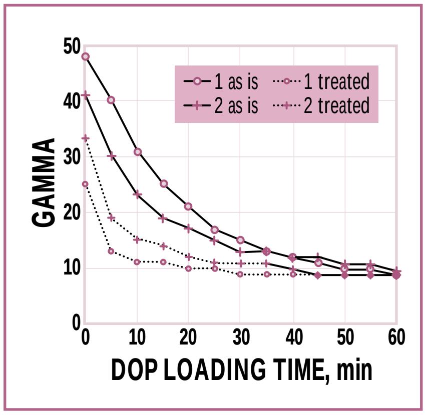
Gamma is a measure of the performance of the filter medium—the efficiency available for a given resistance. **Table I** shows typical values of gamma for various media. For glass medium, geometric factors such as fiber diameter and solidity almost completely determine gamma. A value of gamma for 0.3 µm DOP particles at 5.33 cm/s face velocity will typically be 7–10 for a coarse microfiberglass ASHRAE filter medium and 10–13 for a fine microfiberglass HEPA or ultra low penetrating air (ULPA) filter medium. The value of gamma under the same conditions for an uncharged 3 µm melt blown polypropylene fiber will be 7–10.

With synthetic media, we must consider electrostatic or electret charge. This is usually not the net electrostatic charge. It is charge separation or electret or dipole charge. The presence of such charge or charge separation on a synthetic fiber can dramatically increase the gamma value to 30, 50, or higher. This is the unique advantage that synthetic fibers can have over glass fibers. Glass fibers cannot retain an electret charge.

At this point, we can make a broad generalization. Any media that has a high gamma unexplainable by geometric factors undoubtedly relies



4. Effect of DOP coating on synthetic ASHRAE performance



5. Effect of DOP loading on synthetic ASHRAE performance with and without isopropyl alcohol treatment

on electrostatics or some form of electret charge whether created intentionally or not.

PERFORMANCE DECAY IN LIQUID AEROSOLS

The problem with electrostatic enhancement is decay. **Figure 2** shows the gamma value of a typical electret charged melt blown polypropylene medium under prolonged testing with either 0.3 µm DOP particles or 0.5 µm NaCl particles. Gamma obviously increases with loading of solid aerosol, and it decreases with loading of liquid aerosol. We believe this difference in response to solid and liquid aerosols is general. The solid particles build dendrites that act as filter fibers themselves. The liquid particles wet, coat, and electrostatically shield the electret charge fibers. This effect seems active in all synthetic media that rely on electrostatic charge whether melt blown, electrostatically spun, or tribocharged. An increase in DOP penetration or decrease in DOP gamma therefore is convincing evidence for the presence of electret charge.

Figure 3 shows gamma measured by 0.3 µm particles at 5.33 cm/s for two specific synthetic ASHRAE media under prolonged DOP testing. Gamma clearly decreases from a high initial value of 40 or 50 to a low of 10. This is essentially equivalent to the uncharged medium.

We believe there are two components of this phenomenon of gamma decay. The first component involves wetting and coating of the fiber by the liquid aerosol. This shields the electret charge on the surface. The second component involves a fine particle aerosol carrying a Boltzman distribution of electrostatic charge on its particles *(3)*. Here approximately one third of the particles will have a charge of +1, another third will have a charge of –1, and the remaining third will be neutral. In addition, a small fraction will have a charge of +2 or –2. As liquid aerosol particles wet and coat the fibers, these individual charges can migrate to and neutralize some fixed charges on the surface of the fibers. This cannot occur with solid aerosol, since the charges on a solid particle are not mobile.

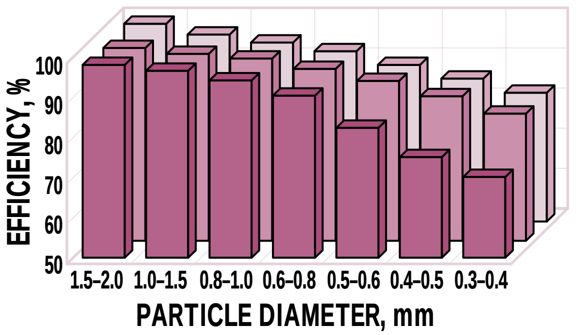
One can demonstrate that liquid coating alone will decay the gamma by saturating charged media with very dilute solutions of DOP in isopropyl alcohol. **Figure 4** shows the value of gamma for the synthetic ASHRAE medium of Fig. 3 as measured with 0.3 µm DOP particles at 5.33 cm/s after saturating with 70/30 isopropyl alcohol/water containing various concentrations of DOP with thorough drying. The alcohol and water evaporate, but the DOP does not. Each sample imbibed roughly ten times its weight of the DOP doped isopropyl alcohol. The value of gamma clearly decreases with increasing pickup of DOP similar to Fig. 3 although not as steeply. It is tempting to attribute the differences between Fig. 3 and Fig. 4 to the added effect of the Boltzman charge. This, of course, would be absent in the isopropyl alcohol experiment.

Many people advocate using isopropyl alcohol saturation as a fast and convenient way to discharge an electrostatically charged sheet. The data above suggest two problems with this method. First, totally pure isopropyl alcohol would probably show no effect after thorough drying. It appears that most of the observed neutralizing effect is due to the presence of tenths of a percent of high boiling impurities in the isopropyl alcohol. This can produce a highly variable result.

As already mentioned, the second problem is a truly electrostatic component of the neutralization that appears absent in the isopropyl alcohol technique. For example, **Fig. 5** compares the DOP decay on media before and after isopropyl alcohol saturation and drying. Isopropyl alcohol treatment has obviously only affected the performance marginally. The gamma can and does decay fur-

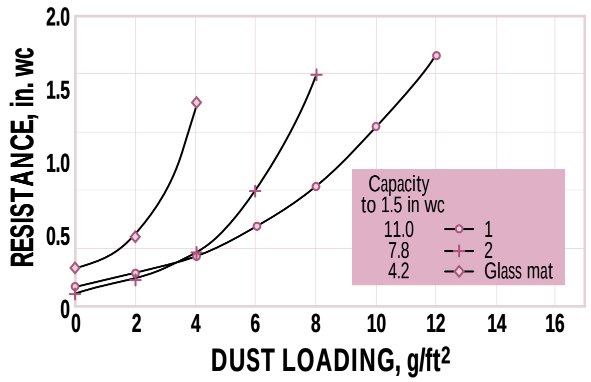
KEYWORDS

Aerosols, air cleaners, air filters, cleaners, colloids, dispersions, efficiency, electric charge, electrostatic charge, fiber mats, filters, glass fibers, inorganic fibers, man made fibers, measurement, separators, sols, synthetic fibers, test methods.



	1.5–2.0	1.0–1.5	0.8–1.0	0.6–0.8	0.5–0.6	0.4–0.5	0.3–0.4	Initial resistance, in.
1	99	97	95	93	90	87	83	.13
2	98	97	96	94	91	87	83	.15
Glass mat	99	97	95	91	84	77	71	.25

6. 90/95 ASHRAE bag initial efficiency



7. 90/95 ASHRAE bag dust loading curves

ther to the ultimate value of 10. While we have not measured directly the decay of these media when challenged with ambient dust, several investigators report behavior similar to that under DOP challenge as in Fig. 3.

DUST LOADING

In much of our development work, we have relied on flat sheet ASHRAE testing by a commercial testing facility. Their test protocol determines the pressure drop and initial efficiencies at a face velocity of 25 ft/min using a laser counter and ambient dust. They incrementally load the sample with ASHRAE test dust while monitoring the pressure drop. The capacity is the dust loading required to produce 1.5 in. water column total pressure drop.

Figure 6 shows the efficiency of two synthetic 90/95 ASHRAE grades compared to a conventional glass mat 90/95 ASHRAE grade. Due to electrostatic enhancement of the melt blown layer, the fine particle efficiency of the synthetic product is higher. The initial resistance is 50% lower. Note again that any synthetic medium showing the combined characteristics of higher efficiency and lower pressure drop than glass is undoubtedly relying on electrostatic enhancement whether intentional or not.

Figure 7 shows the dust loading curve of the same three media. The synthetic media clearly have a higher capacity for ASHRAE dust than the glass mat product. The lower capacity synthetic has an 85 g/m^2 latex bonded air-laid layer combined with a charged melt blown and spunbond scrim. The higher capacity synthetic has a 115 g/m^2 thermally bonded dry-laid layer with a melt blown/spunbond combination. We believe that the total thickness of the high loft layer largely determines the capacity. A common term for this is capacity layer. Fiber fineness and degree of electrostatic enhancement in the bottom or efficiency layer determine the efficiency.

CONCLUSION

Synthetic media are now valid alternates to all glass media for ASHRAE applications. The synthetics offer the advantage of higher efficiency at lower resistance with significantly higher capacity. The main deficiency with synthetic media is the potential decay in efficiency when asaulted by oily aerosols. To deal with all these aspects of the new media, we must be very clear about what we are measuring and the important measurements. **TJ**

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