The synergistic relationship between web structure and charge distribution has been demonstrated as key to the performance characteristics of electret HVAC media. David L Myers and B Dean Arnold, Nonwoven Fabrics, Kimberly-Clark Corp, USA, report field study data for both electrically charged and non-charged media of the same structure, and also present evidence showing that the 2-propanol conditioning of electret filters has a detrimental effect on the media.

Mechano-electret Filtration Media: Synergy of Structure and Electrostatic Charge

The proliferation of electrostatically charged filtration media in both the commercial/industrial and consumer filtration markets has been accompanied by several misconceptions regarding this important class of media. Chief among these is the tendency toward grouping all electrostatically charged media together as if all were the same. In this article we highlight the filtration performance characteristics of continuous filament melt-spun (CFM) media, which have been electrically charged to create a unique combination of structure and electrostatic charge. We present field study data collected for both electrically charged and non-charged media of the same structure, which illustrates the underlying mechanical filtration properties of the CFM media structure. In addition, long-term aging data is presented in support of the stability of the electrostatic charge on the media. A critical evaluation is presented on the effects of the '2-propanol conditioning' step. Experimental evidence will be discussed which clearly shows that 2-propanol interacts with nonwoven media altering their filtration properties, and yielding a material quite unlike a non-electret charged media.

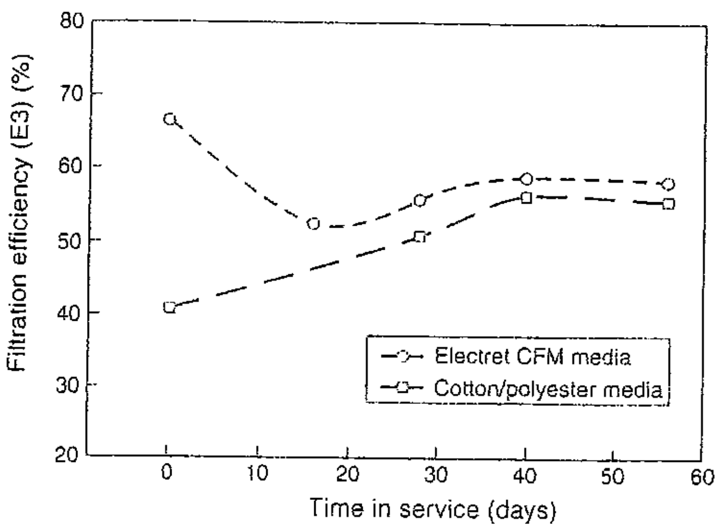

Figure 1: Pleated filter field study conducted at a hospital site using 100% outdoor air (filtration efficiency is the average efficiency over the particle size of 3-10 microns for a 20" x 20" x 2" filter at a face velocity of 492 fpm).

EXPERIMENTAL SET-UP

(i) Materials

CFM filtration media were manufactured in accordance with the teachings of the following United States (US) patents: 4 340 563 to Appel *et al*, 3 692 618 to Dorschner *et al*; 3 802 817 to Matsuki *et al*; 3 338 992 & 3 341 394 to Kinney; 3 502 763 to Hartman; 3 542 615 to Dobo *et al*; and 5 382 400 & 5 795 926 to Pike *et al*. The electret charging of CFM media was accomplished according to the teachings of Tsai *et al* in US patent 5 401 446. Polyethylene and polypropylene used in the manufacture of CFM media and film materials were obtained from commercial sources within the USA. All other reagent grade chemicals were obtained from Sigma-Aldrich Inc

(ii) Filtration Testing

Flat sheet samples of filter media were tested using either a TSI 8110 automated filtration tester operated at a flow rate of 32 l/min using a sodium chloride (NaCl) challenge aerosol (TSI Inc, Minneapolis, Minnesota, USA). ASHRAE 52.2 filtration testing was performed at LMS Technologies Inc (Bloomington, Minnesota, USA) in compliance with guidelines set forth in the ANSI/ASHRAE 52.2 Standard

RESULTS & DISCUSSION

(i) HVAC Field Studies

The in-service filtration performance of heating, ventilation and air conditioning (HVAC) media was measured for purely mechanical filtration media, a non-electret CFM media, and an electret CFM media. The purely mechanical media was a 2.6 oz yd^2 (osy) cotton-polyester HVAC media chosen to accurately represent the in-use performance of this class of filter media. The electret CFM media was a 2.0 osy bicomponent polyolefin filter media charged by the corona poling method. The non-electret CFM media was identical in structure to the electret CFM media with the exception that the media was not charged. All the filter media were evaluated as pleat filters wherein the pleating characteristics were the same for each material. Sample filters prepared with each media type were subjected to operating environments that utilized 100% outdoor air, 100% indoor air, and a mixture of recirculated (indoor) and make-up (outdoor) air.

(i) Outdoor Air Environment

Pleated filters were installed in the pre-filter bank of a two- stage filtration system servicing a hospital located in the Chicago area (Illinois, USA). Filters remained in the unit for a period of two months. Filters were removed from the system at various time intervals to characterize the filtration performance as the media became loaded during actual use.

The actual filtration performance (Figure 1) shows that the filtration efficiency (average efficiency for 3-10 micron particles, E3 value for ASHRAE 52.2) of the electret CFM media decreases over the first 15 days of the test. The decay in efficiency can be attributed to the capture of fine particle contaminants from the outdoor air as it passes through the media. Notably, the decrease in efficiency during this time period was <20% relative to the efficiency of a virgin filter. In addition, as the dust cake accumulates within the electret CFM media, the filtration efficiency recovers to a level, only 10% below that of the new filter. Initially, the purely mechanical cotton-polyester media had a filtration efficiency that was 40% below that of the electret CFM media. While the efficiency of the mechanical media increased steadily over the course of the test, it never exceeded the filtration performance of the electret media.

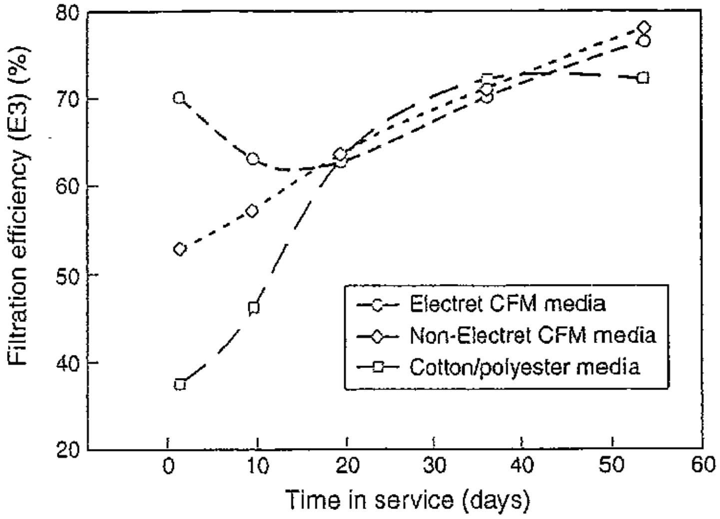

Figure 2: Pleated filter field study conducted at a hospital site using 100% outdoor air (filtration efficiency is the average efficiency over the particle size of 3-10 microns for a 16" x 25" x 2" filter at face velocity of 295 fpm).

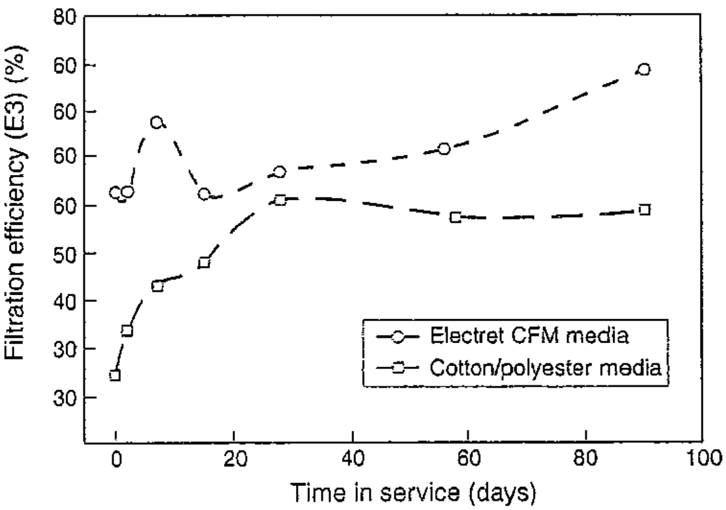

Figure 3: Pleated filter field study conducted at a residential locations using 100% indoor air (filtration efficiency is the average efficiency over the particle size of 3-10 microns for a 20" x 20" x 1" filter at face velocity of 295 fpm).

The outdoor air exposure study was extended to include a second hospital in the Memphis area (Tennessee, USA). Filters were produced using non-electret CFM, electret CFM, and cotton-polyester media described above. As shown in Figure 2, the electret CFM media drops in efficiency over the first 10-15 days in-service, and then regains efficiency as it loads with dust. The non-electret CFM media had an initial efficiency intermediate between that of the electret and cotton-polyester media. Its efficiency increases over the course of the test as the structure steadily builds mechanical efficiency during dust loading. The same behavior was observed for the cotton-polyester medium, but its initial efficiency was approximately half that of the electret media, and it was in service for approximately one month prior to achieving parity performance to either of the CFM media types tested.

(ii) Indoor Air Environment

Pleated filters made using electret CFM media and mechanical cotton/polyester media were tested at residential locations in the

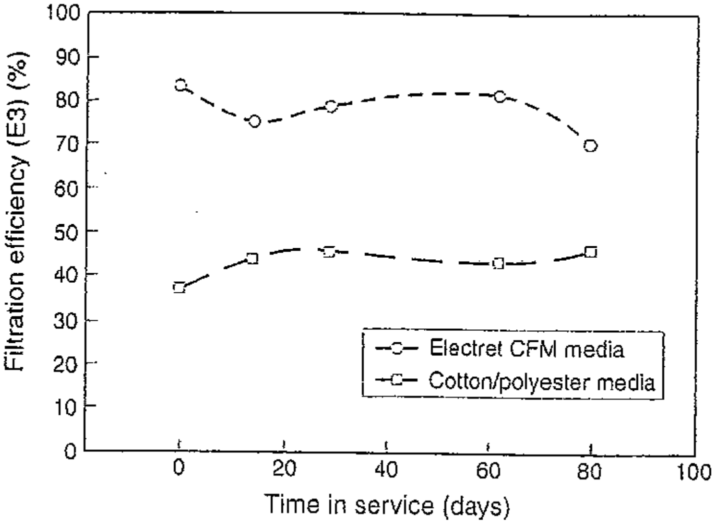

Figure 4: Pleated filter field study conducted at an office building, using a mixture of indoor and outdoor air (filtration efficiency is the average efficiency over the particle size of 3-10 microns for a 24" x 24" x 4" filter at face velocity of 492 fpm).

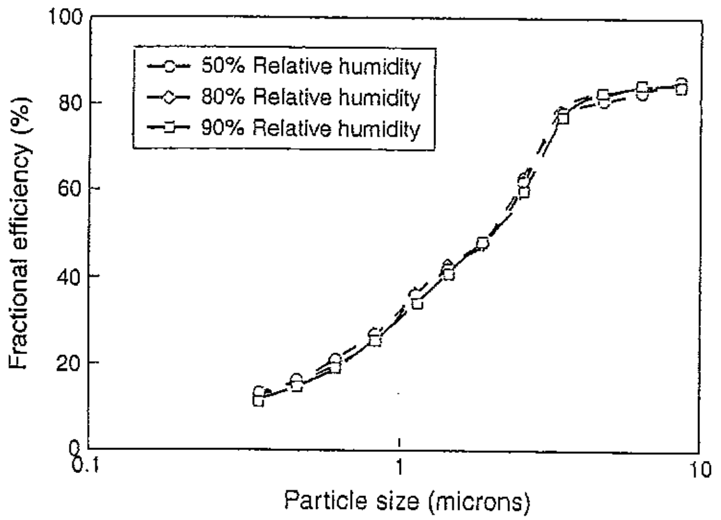

Figure 5: Fractional filtration efficiency of electret CFM media tested as a flat sheet, where the relative humidity of the challenge aerosol varied from 50% to 90% at a temperature of 21 °C.

Atlanta area (Georgia, USA). The ASHRAE 52.2 dust removal efficiency of these filters is shown in Figure 3. The initial efficiency of the electret CFM media is more than twice that of the cotton/polyester media. Initially, the electret CFM media displayed a small increase in efficiency after 10 days in-use. Examination of the filter indicated a large percentage of the contaminant present was in the form of small fibre fragments. It is believed that the presence of these fragments alters the mechanical filtration properties of the electret CFM media. Independent of this initial increase in efficiency, the electret CFM media displays a monotonic increase in efficiency with time in-service. Notably, the cotton/polyester media also displays a steady increase in efficiency with time in-service, indicative of increasing mechanical efficiency. However, the cotton/polyester media reaches a maximum efficiency of 60% after one month, and does not achieve parity performance with the electret CFM media.

(iii) Mix of Outdoor & Indoor Air

The final field study presented here involves the exposure of pleated filters to a mixture of outdoor (fresh) air and indoor (recycled) air. The study was performed in an office building within the Atlanta metropolitan area. The dust removal efficiency of these pleated filters after up to 80 days of exposure is shown in Figure 4. Notably, the cotton/polyester mechanical media reaches a maximum efficiency after 15 days in-use. The efficiency remains unchanged for the duration of the study. The electret CFM media initially has an efficiency more that twice that of the cotton/polyester media and maintains roughly a 2 fold advantage for the duration of the study.

(iv) Effects of Humidity on Filtration Properties

Electret CFM media was tested in accordance with the ASHRAE 52.2 protocol as a function of increasing relative humidity in the challenge aerosol stream. Flat sheet media samples were tested for fractional filtration efficiency at normal conditions , i.e. 21 °C and 50% relative humidity (rh), and media face velocity of 110 fpm. The same media sample was then conditioned at 80% rh and then 90% rh, and was retested under these conditions. The fractional filtration efficiency at each humidity level is shown in Figure 5. Notably, the filtration efficiency was unaffected by relative humidity.

(v) Effects of Long Term Storage on Filtration Properties

A number of concerns have been raised over the long-term stability of electret CFM media. Concern has focused on a loss of efficiency due to a decay of the electret charge present within the media structure. Newly manufactured electret CFM media were tested for fractional efficiency in accordance with ASHRAE 52.2. The media were then packaged and stored in warehouse inventory for one and two years and then retested. Figure 6 shows that there is no significant difference in the efficiency of newly produced media and media aged for either one or two years.

(vi) Conditioning Treatments for Electrostatic Filtration Media

It has been proposed that the mechanical filtration properties of electrostatically charged filtration media can be evaluated by first dipping the media in a 2-propanol bath prior to testing. The 2-propanol wash is intended to remove the electrostatic treatment yielding a non-charged media for testing. In the study presented here, the filtration properties of filter media before and after 2-propanol exposure were measured using a TSI Model 8110 filtration tester with a NaCl challenge aerosol.

For liquid exposure, samples of media were immersed in 2-propanol for 10 min followed by air-drying for 12 h and oven drying at 80 °C (the boiling point of 2-propanol) for 0.5 h. The data are shown in Table 1.

The data provide a direct comparison between samples of media tested prior to electret charging, after electret charging, and after electret charging and immersion in 2-propanol. Notably, electret charging of each of the media types leads to a marked improvement in filtration efficiency. In addition, while immersing the media in 2-propanol clearly leads to deterioration in filtration efficiency; it does not restore the media to its original uncharged state.

The changes observed in filtration properties observed following 2-propanol immersion are due to penetration of the solvent into the polymer matrix. This causes irreversible changes to the polymer, which results in a decay in filtration properties. It is possible that the 2-propanol gives rise to conductive pathways in the bulk polymer leading to charge recombination or compensation. However, the fact that the filtration properties of media that have been immersed in solvent are not the same as those of non-electret media invalidates the 2-propanol immersion as a conditioning step.

CONCLUSIONS

The comprehensive field studies of pleated filters made using electret CFM media and purely mechanical cotton/polyester media clearly demonstrate the overall superiority of the electret CFM media over the lifespan of the filter. While small particle contaminants were observed to cause decay in the efficiency early in the lifetime of electret CFM media, the building of mechanical efficiency in these filters compensates for this loss and yields a filtering medium with better initial efficiency and better long term filtration efficiency as compared to cotton/polyester media of equivalent basis weight. In addition, it was shown that non-electret CFM media also provide better initial efficiency as compared to cotton/polyester media and maintain parity performance to the same over lifetime of the filter. The combination of structure and electret charge, which exists in the electret CFM media yields a more efficient filter overall.

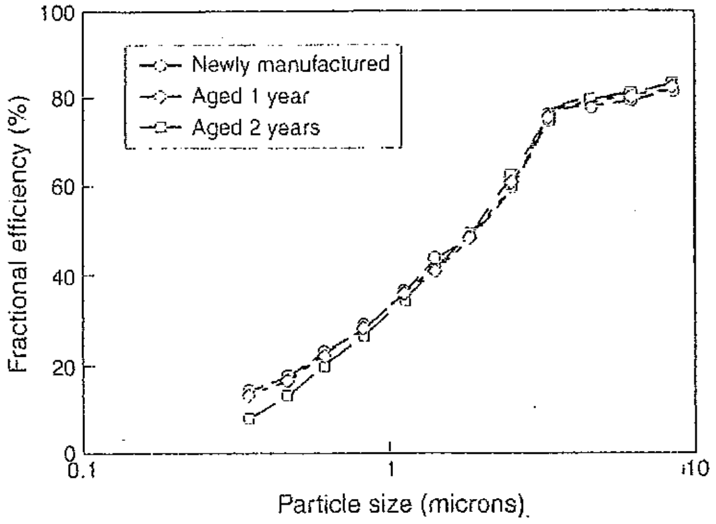

Figure 6: Fractional filtration efficiency of electret CFM media as manufactured and following storage in a non-temperature controlled environment for up to two years.

In addition, evidence has been presented which refutes the use of 'conditioning treatments' which decouple electrostatic effects from mechanical efficiency. The 2-propanol immersion was clearly shown to cause irreversible changes to electrostatically charged media, which are related to dissolution of low molecular weight polymer by the solvent. Once exposed, the 2-propanol is at best difficult and at worst impossible to remove from the polymers used in manufacturing electret CFM media. Thus, rather than being a passive treatment, the 2-propanol immersion yields material with vastly different mechanical and filtration properties, which do not reflect those of non-electret charged media of the same structure.

Contact:

David L Myers or B Dean Arnold,
Filtration Products, Kimberly-Clark Corp,
1400 Holcomb Bridge Rd,
Roswell, GA 30076, USA.
Tel:+1 770 587 8000
Fax. +1 770 587 7241
Website: www.kcfiltration.com

The article is based on a presention made at the 5th Annual Conference on Nonwovens in Filtration, on March 12, 2003. The conference, which was held in Stuttgart, Germany, was sponsored by the European Disposables and Nonwovens Association (EDANA) and hosted by Filter Media Consulting Inc, USA.

Table 1: 2-propanol exposure of electrostatically charged filtration media

Filter Media	Non-electret (% efficiency)	Electret (% efficiency)	2-propanol washed (% efficiency)
PE/PP CFM media	5 0 ±1.8	50 6 ±3 0	10 3 ±1 6
PP spunbond media	9.5 ±1.2	57 5 ±1 7	17 7 ±2 5
PP melt-blown media	58 1 ±1.1	93 8 ±0 6	83 5 ±1 6