# BENEFITS OF NONWOVEN STRUCTURE ON ADSORPTION PERFORMANCE OF NOVEL FILTER MEDIUM

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***Abstract***
This paper will introduce a novel application of nonwoven technology to create a unique material for the filtration market. This technology produces a 3-dimensional matrix of nonwoven fiber and functional particles without the use of additional binders. The structure of this medium offers improvements in gas and odor adsorption when compared to alternative filter technologies. These improvements will be documented and traced back to the changes that are made possible by the aforementioned structure.

## Introduction
Removal of gaseous or molecular airborne contaminants is becoming increasingly important across a broad range of indoor air quality applications. Semiconductor manufacturing processes and products are sensitive to a variety of contaminants including acid gases, volatile organics, and amines at the low ppb and even ppt levels. Cleanrooms in the semiconductor industry are incorporating gas phase filters in both make-up and recirculation air units to control these contaminants. Other industrial uses include the protection of sensitive electronics from the same contaminants. Institutional uses include the protection of sensitive materials and archives. Office, hospitality and retail uses include the removal of odors from the offgassing of building materials, cooking, tobacco smoke, and the intake of diesel and other exhaust or materials. Consumer uses are primarily for removal of tobacco, pet, and cooking odors.

## Variety of Solutions Available
A variety of gas phase media and filters are available to address these concerns. These can generally be divided into three types. Carbon-powder, slurry-coated nonwovens are inexpensive and have very low pressure drop, but have relatively poor adsorption performance due to the small amount of carbon present and the fact that much of it is covered with adhesive. Granular activated carbon (GAC) trays are perhaps the best known, and are available in a wide range of price and performance combinations. These are typically large systems requiring significant labor for changeout, and are used for “industrial” applications with relatively high contaminant levels. Performance can be quite variable depending on how the trays are manufactured and installed. They are also subject to dusting downstream as the carbon particles abrade each other. Granular activated carbon-loaded nonwovens are a relatively new “hybrid” product which, with the proper construction and application, can offer extremely high value in terms of high efficiency and good capacity or service life, as well as low pressure drop and ease of handling. This type of product has been widely accepted in the semiconductor cleanroom industry.

## Novel Carbon-Loaded Nonwoven

AQF Technologies LLC has developed a patented product and technology that produces a 3-dimensional matrix of nonwoven fiber and functional particles that does not require the use of additional binders. This product, shown in cross-section in Figure 1, uses a carded bicomponent staple fiber and activated carbon to form a material with a unique combination of performance properties.

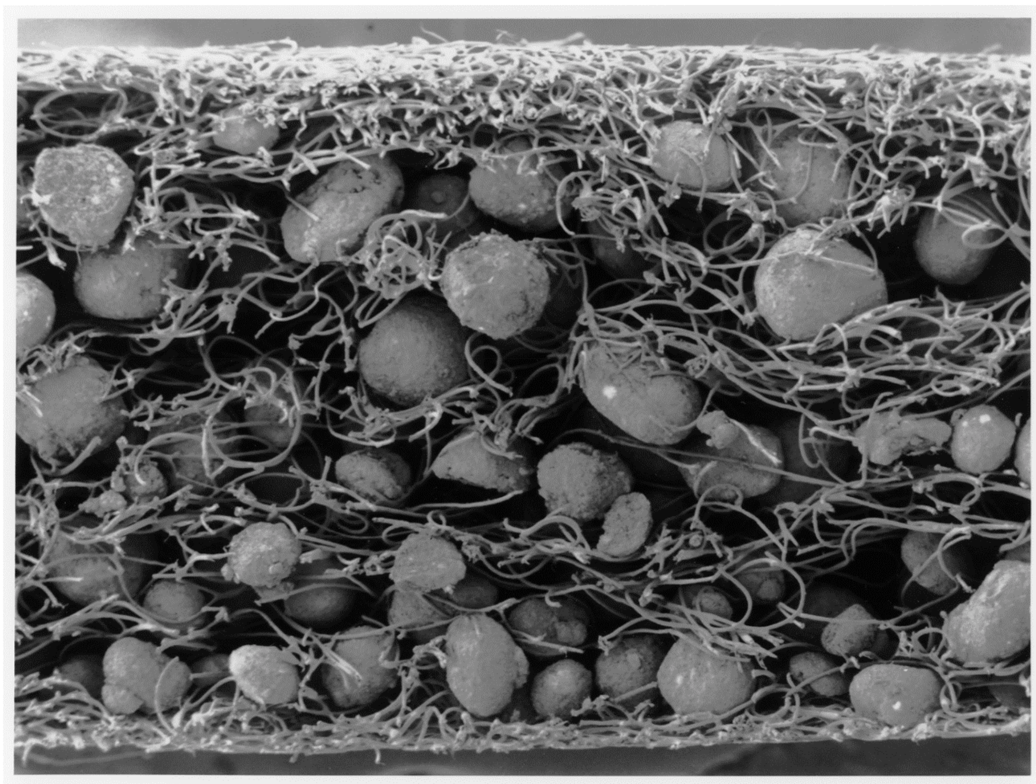

**Figure 1. Cross-section of new Carbon-Loaded Nonwoven Filtration Medium, 50x Magnification.**

Figure 2 shows a cross-section of the bicomponent fiber with its low-melt sheath and high-strength core. The sheath provides bonding for creating the nonwoven structure and immobilizing the carbon granules while the core provides strength for handling, converting, and application. When heat-treated the fibers form an intimate bond with each other and with the carbon particles (Figure 3). The result is a robust, pleatable roll good with many advantages over existing alternatives.

## Benefits of Nonwoven Structure

There are three primary features to this new carbon-loaded nonwoven product. These are the ability to use smaller particles, the maximization of available surface area, and the creation of a controlled tortuous path for airflow through the functional particles. These three features combine to give higher initial efficiencies and lower pressure drops than competitive technologies. Of course, there are numerous other factors that impact the efficiency of a filter including media velocity, carbon source, carbon activity and quality, type and concentration of contaminant, type and level of impregnation of the carbon, and different types of functional particles. However, these factors are not restricted to any one company except through supplier relationships.

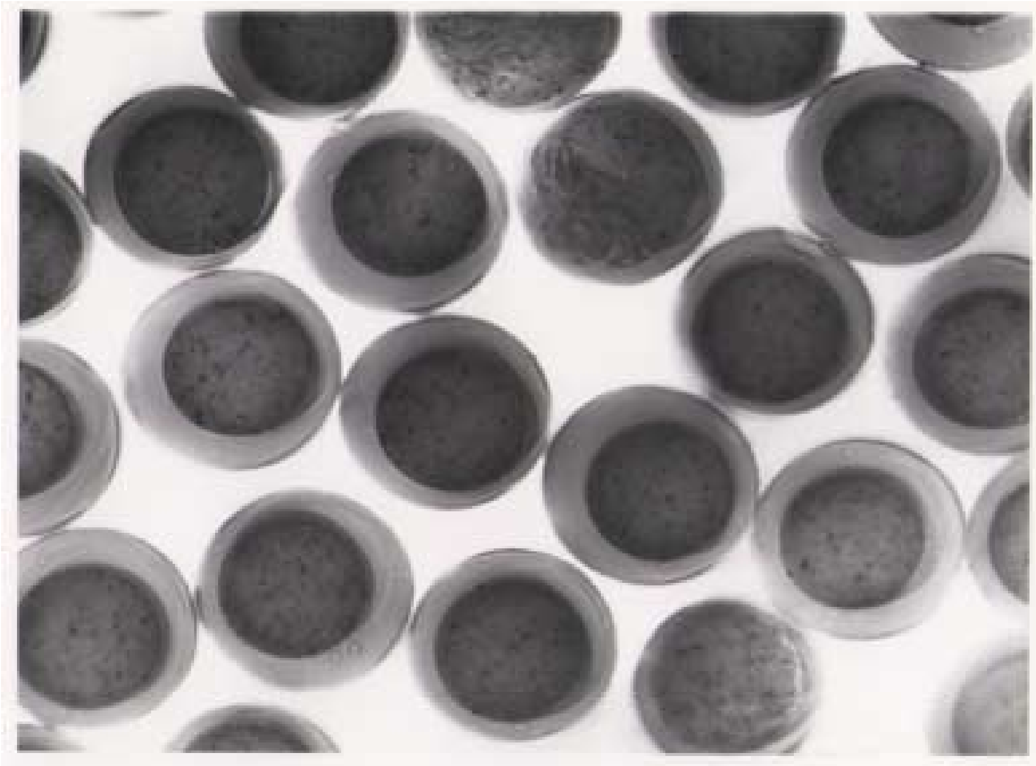

**Figure 2. Cross-section of Bicomponent Fiber Used in Carbon-Loaded Nonwoven, 1000x Magnification.**

The impact of smaller particles on removal efficiency is shown in Figure 4. This figure shows the percent breakthrough of toluene through the same weight of loose-filled carbon of two different sizes. The sizes are represented by mesh size, which is inversely related to particle size. Note the lower breakthrough for the smaller particles throughout the useful life of the material (defined by the time it takes to reach 50% breakthrough). Figure 5 shows a similar effect with sulfur dioxide, a reactive gas that is chemisorbed on activated carbon. The impact of particle size is thought to be due to the increased access which the airflow and contaminant have to the adsorbent surfaces of the activated carbon, both external and internal.

The vast majority of the surface area of an activated carbon granule is inside the particle. But, to be effective, the contaminant must diffuse into the particle to come in contact with these adsorption surfaces. The smaller the granular particles are, the quicker the contaminants from the air stream can reach the interior adsorption surfaces and the less concentration gradient is needed. On average, the particles in a 20x50-mesh carbon are 7 times smaller in diameter than those in a 4x8-mesh carbon. While the total surface area available for adsorption and therefore the total amount of contaminant that can be adsorbed is not significantly increased with the smaller particles, the adsorption is shifted to the earlier part of the media life.

**Figure 3. Fiber-to-Fiber and Fiber-to-Carbon Bonding.**

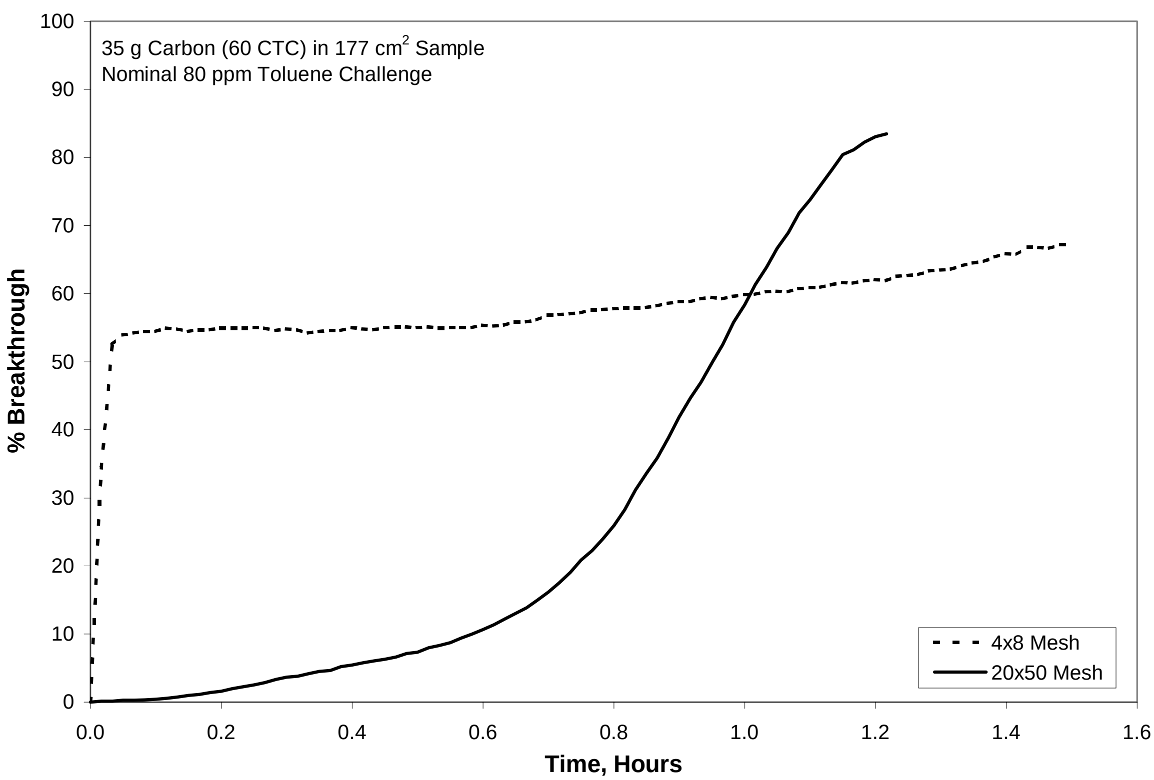


**Figure 4. Toluene Breakthrough vs. Particle Size.**

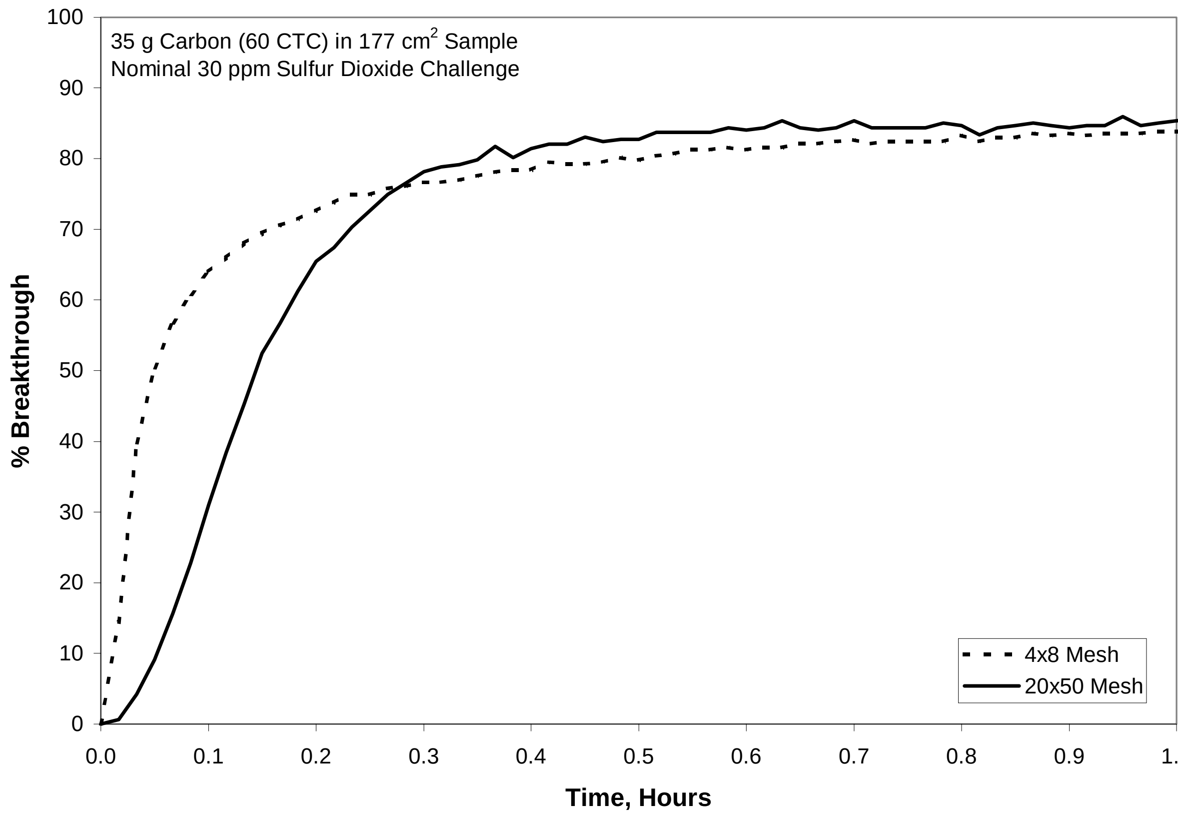


**Figure 5. Sulfur Dioxide Breakthrough vs. Particle Size.**

Loose carbon trays typically use particles that are 4x8 mesh due to pressure drop concerns. When particles are packed together there is little space between the particles for airflow. Thus, the resistance to flow or pressure drop is high. The smaller the particles are the higher the pressure drop is at a given airflow. But thin nonwoven media can be pleated, dramatically increasing the area for airflow. Therefore, this new product can use much smaller particles (20x50 mesh currently) while still maintaining low pressure drop.

Based on the particle size effect alone, the powdered carbon, slurry-coated materials would have an even larger advantage since powdered carbons are even smaller in size, being 325 mesh and finer. However, for this to be true the air stream must have access to the surface area of the carbon. With slurry carbons this access is defeated by the binder materials used in the slurry process. These binders coat a significant portion of the carbon surface, blocking contact with both the external and internal adsorption surfaces as shown in Figure 6. This reduces both the initial efficiency and the total amount of contaminant that can be adsorbed.

The new nonwoven structure however, maximizes access to the carbon adsorption surfaces. Notice in Figure 3 that the bond between the bicomponent fiber and the carbon granule covers a very small portion of the surface. In fact, approximately 99% of the carbon's outer surface area is left open. Yet these point bonds are sufficient to immobilize the particles within the nonwoven structure, eliminating shedding and dusting of particles downstream of the filter.

Figure 7 shows a comparison of the adsorption performance of several slurry products with the new nonwoven media. Even a nonwoven product with a carbon loading of only 100 gsm outperforms the slurry material.

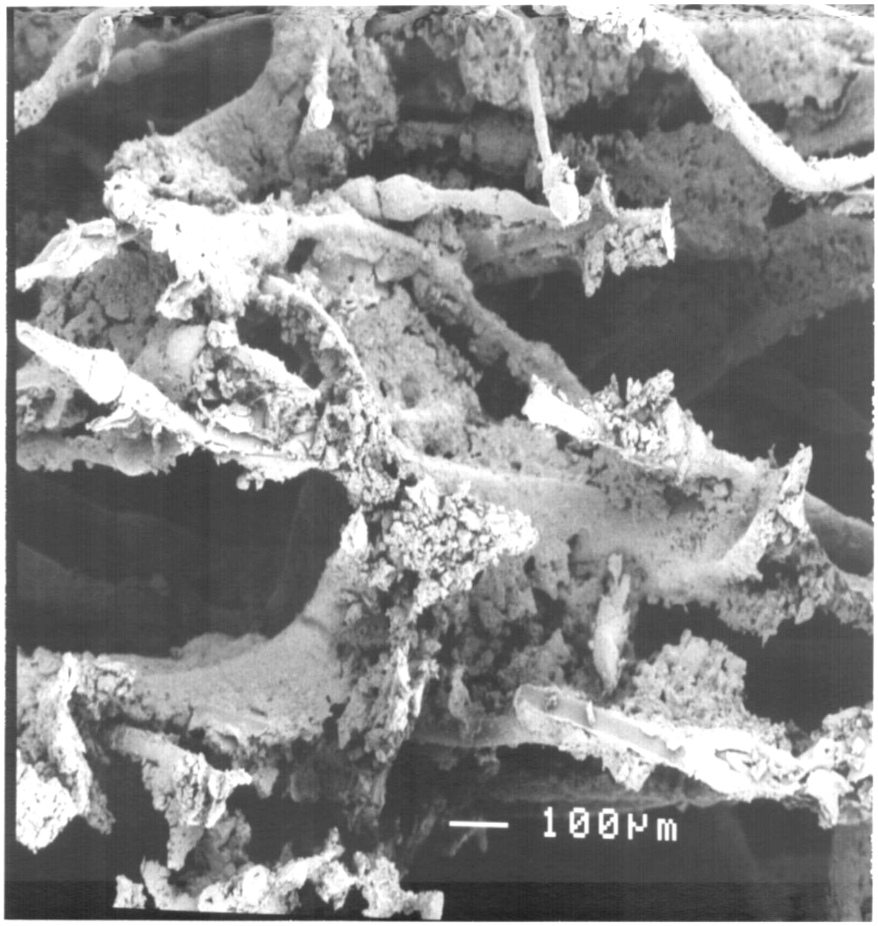


**Figure 6. Powdered Carbon, Slurry-Coated Nonwoven.**

The last feature of the new nonwoven product is the creation of uniform void space between the granular particles. This creates a tortuous path for airflow through the nonwoven medium, providing uniform access to the carbon granules at the same time that it lowers pressure drop. The void space is created by evenly distributing the carbon granules throughout the nonwoven in three dimensions as shown in Figure 1. It has been compared to a frozen fluidized bed of particles. This is in contrast to other carbon-loaded nonwovens that sandwich a layer of carbon between layers of nonwoven. The combination of controlled void space within the medium and the ability to pleat the nonwoven leads to much lower pressure drop than other carbon filtration systems.

An added benefit created by the tortuous path through the 3-dimensional matrix is a reduction in "bypass". Bypass refers to situations where portions of the airflow never come in contact with the functional particles. This can happen for any filter when the carbon loading gets very low. However, the high pressure drop through packed particles and nonuniform packing in loose beds creates another opportunity for airflow to travel preferentially through loosely packed sections or around the edges of the bed. This leads to higher velocities through portions of the bed while other sections are effectively bypassed by the airflow, increasing the initial breakthrough of the contaminant through the filter.

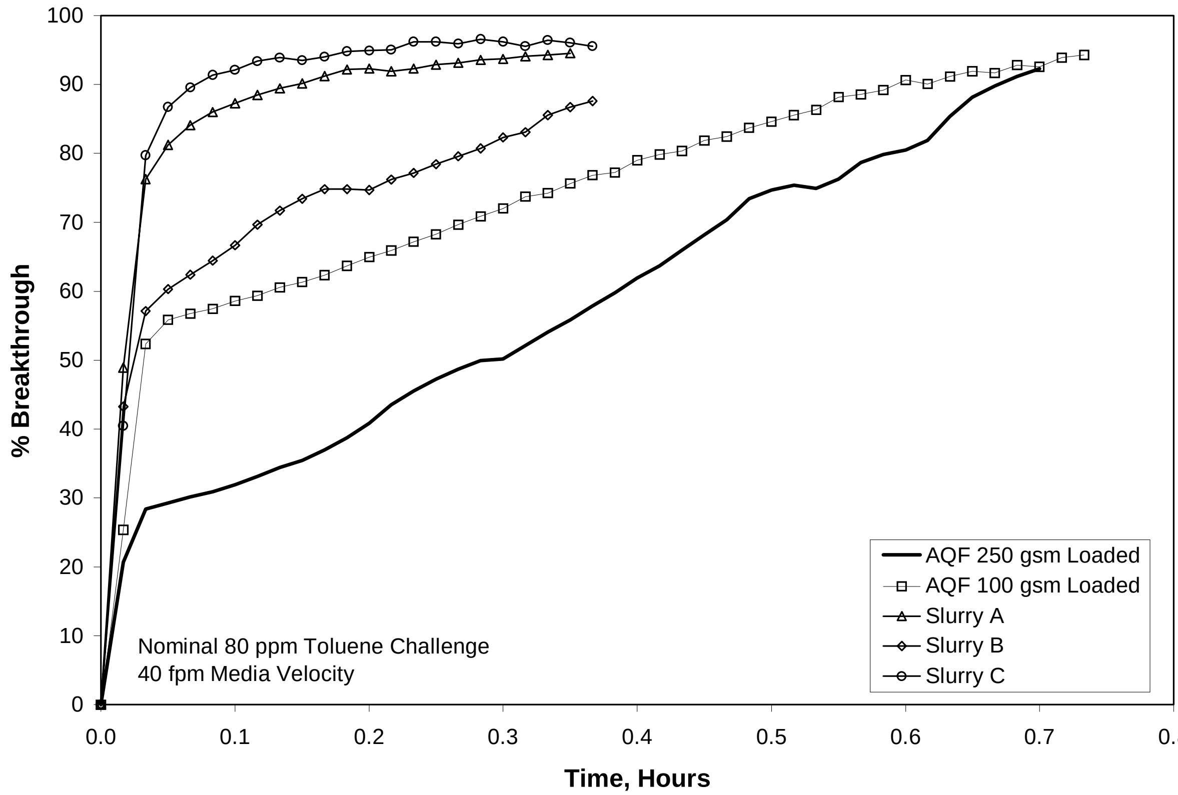


**Figure 7. Toluene Breakthrough of Slurry Coated Products and Novel Nonwoven.**

A comparison of pleated filters using the novel nonwoven to loose carbon panels is shown in Figure 8. This comparison shows two grades of nonwoven media (250 gsm and 500 gsm loaded) in a pleated V-bank construction versus several carbon panel formats. Notice the initial breakthroughs ranging from 20 to 50% for the carbon panels versus <10% for the nonwoven material. This is despite the fact that there are only 6.5 pounds of carbon in the pleated filter construction and anywhere from 9-26 pounds in the carbon panel formats. The pressure drops are also dramatically different: 0.15" of $H_2O$ for the pleated nonwoven filter system and 0.28-0.55" of $H_2O$ for the carbon panel constructions.

## Summary

The conclusion from the above is that the unique application of nonwoven technology allows us to take advantage of several technical factors that improve filtration efficiency without sacrificing other key performance parameters. This technology is dependent on the use of a nonwoven structure to immobilize functional particles in an evenly distributed 3-dimensional matrix. This matrix allows the use of smaller particles, ensures a uniformly distributed airflow to the particles, and doesn't cover the adsorption area, leading to higher initial efficiencies than alternative systems. The controlled void space between the functional particles and the ability to pleat the medium give lower pressure drop. The result is a unique and effective material for filtration of low concentration odors and gases in a variety of applications. Many of these benefits have application in the removal of contaminants from liquid streams as well.

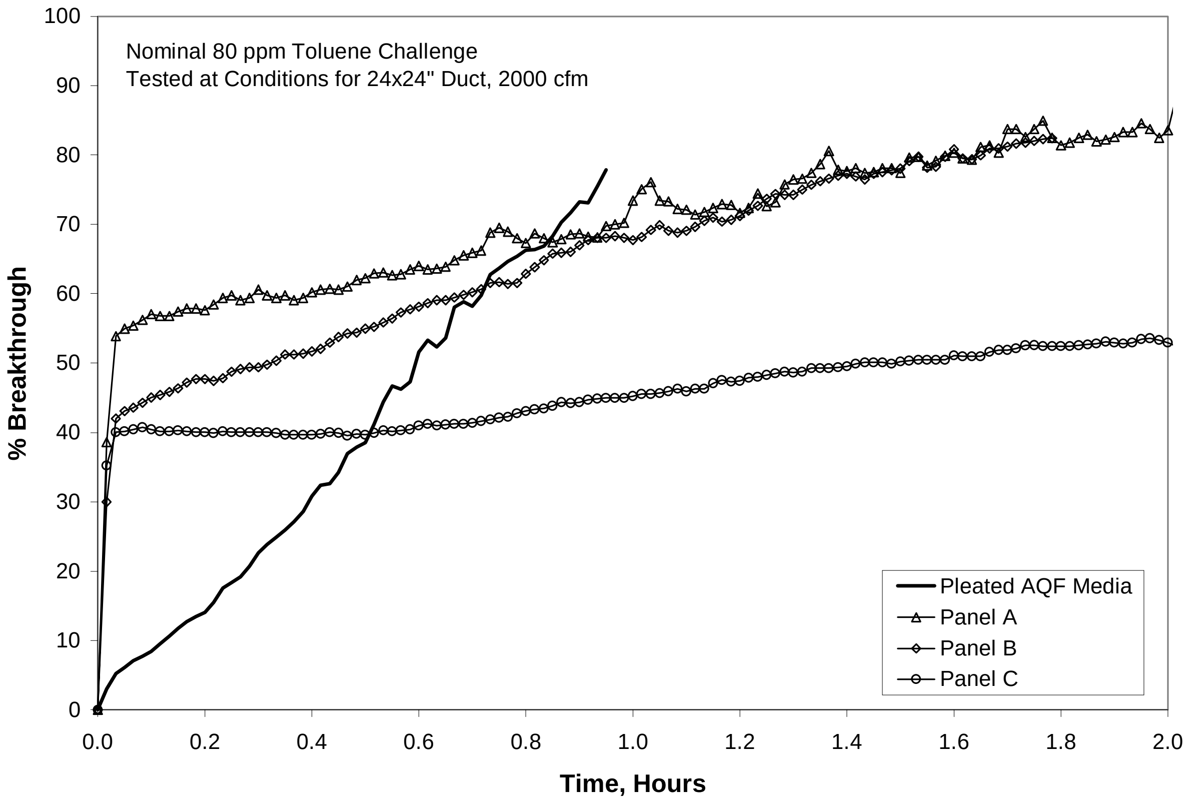


**Figure 8. Toluene Breakthrough of Loose Carbon Panels and Pleated Nonwoven.**


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