

ENHANCED ARAMID FELT FILTER BAGS WITH NEW EXPANDED PTFE MEMBRANE TECHNOLOGY

by

Thomas C. Savage
Robert C. Carlozzi
Ole Petzoldt
W. L. Gore & Associates

INTRODUCTION

The field of industrial air filtration has changed significantly over the past 20 years. In that time, pulse jet dust collectors have emerged as the technology of choice for industrial applications. Several factors have influenced this evolution, such as:

1. A need for increased filtration capacity within the same or smaller area (“footprint”)
2. New stricter emission regulations for fine dust particulate such as EPA PM₁₀ and PM_{2.5} regulations
3. Increased use of dust collectors for product collection versus pollution control

The need for increased air handling capacity has become more important as existing industrial facilities seek expansion. Pulse jet baghouses are optimal for applications requiring low to medium gas volume processing¹. This baghouse design offers a significantly smaller footprint compared to other technologies. For example, to handle 170,000 m³/h (100,000 acfm) of gas flow, a

typical reverse air baghouse would have a footprint of approximately 55 m² (600 ft²). Alternatively, a pulse jet collector designed for the same gas flow would have a footprint of close to 37 m² (400 ft²). The 35% reduction in footprint is a clear advantage if facility size is a constraint.

The filter material used in a pulse jet collector can be either a woven fabric or a nonwoven needlefelt. Felt structures are usually thicker and have a more random fiber arrangement than woven fabrics. Needlefelts are composed of short staple fibers needled into a supporting scrim or simply needled together, as in the case of scrimless felts. The intricate entanglement of these fibers enhances the particulate matter capture capability of the product. The most difficult particles to capture are those in the 0.1-0.3 micron diameter size range. These relationships are described by Rubow et al.² The better filtration efficiency of the felt helps to reduce emissions or increase product yield depending on the function of the system.

The pulse jet collector relies on a high-energy burst (or pulse) of compressed gas to clean the filter. The increased mechanical

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wear associated with this type of cleaning generally rules out the use of fabric. In general, woven fabrics are not as resistant to mechanical flexing, especially if they are made from fiberglass. As a result of the better filtration and mechanical properties, the filtration media of choice is usually a nonwoven needlefelt.

The design and operation of a pulse jet collector are important to achieve the best performance. Equally important is the design of the filter media. In parallel with the improvements in the dust collector design, companies have been researching ways to improve the performance of filter media. These research efforts have focused on two critical areas:

1. Improving the chemical and physical properties of the filter materials
2. Increasing the filtration efficiency and durability of the filter

This paper focuses on the development efforts that have led to AMAZON filter bags, an improved ePTFE membrane/aramid felt filter media. This new media represents an important step forward in filtration technology.

ARAMID FELT IN PULSE JET BAGHOUSES FOR INDUSTRIAL FILTRATION

Aramid fibers possess very good chemical resistance compared to other fibers, especially in the 150-180°C (300-350°F) range. Aramid felt filters are also among the most abrasion resistant. In dust collection applications, the ability of the filter to resist abrasion damage from the support cage, the gas stream, and particulate is important. Table 1³ shows the chemical and abrasion

resistance of a number of fibers typically used in filtration.

Fabric	Max. Cont. Temp.	Acid Resistance	Fluoride Resistance	Fluoride Resistance	Alkali Resistance	Flex Abrasion Resistance
Cotton	180°F	Poor	Poor	Poor	Good	Very good
Polypropylene	200°F	Excellent	Poor	Poor	Excellent	Very good
Polyester	275°F	Good	Poor to fair	Poor to fair	Good	Very good
RYTON®	375°F	Good	Good	Good	Very good	Very good
NOMEX® (aramid)	400°F	Poor to fair	Good	Good	Excellent	Excellent
TEFLON®	450°F	Excellent	Excellent	Excellent	Excellent	Fair
Glass felt	500°F	Good	Poor	Poor	Fair	Fair
Woven fiberglass	500°F	Fair to good	Poor	Poor	Fair to good	Fair
P-84	500°F	Fair	Fair to good	Fair to good	Fair	Good

Table 1: Fabric Selection Chart

The weak link for the aramid fiber has been its susceptibility to hydrolysis and acid attack in applications with moisture at temperatures above 150°C (300°F). Hydrolysis is defined as “a chemical reaction in which water reacts with another substance to form two or more new substances.”⁴ If there are acids present in the gas stream, the chemical reaction will be catalyzed and damage to the aramid fiber will occur faster. For aramid the reaction is shown as:

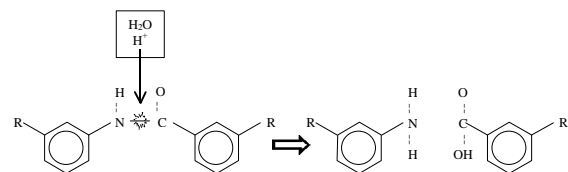


Figure 1: Chemical equation for hydrolysis reaction of aramid

When hydrolysis occurs, the molecular chains of the aramid fiber are broken, thus decreasing the mechanical strength of the felt. A filter that has been hydrolyzed will appear darker in color and be less flexible than a new, unused filter.

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NEW PRODUCT

A new composite filter media has been developed that improves the physical and chemical properties of aramid while also increasing filtration efficiency. Filter bags incorporating this filter media are sold under the tradename AMAZON and combine a proprietary acid resistant aramid felt with a new, patented GORE-TEX® ePTFE membrane. The unique acid-resistant treatment reduces the detrimental impact of hydrolysis by protecting the aramid fibers. The patented ePTFE membrane improves filtration efficiency and durability.

Chemical Resistance Properties

The relative resistances of several different commercially available aramid felts to sulfuric acid attack were tested at the University of Massachusetts at Dartmouth, Textile Sciences Department. Sulfuric acid was chosen for its ability to rapidly hydrolyze aramid polymer structures and because it is commonly found in filtration applications where aramid filters are used. Currently, there is no standard test for determining the resistance of various filter media to sulfuric acid. A new test protocol was developed by the researchers. The test protocol has been submitted to the Association of the Nonwoven Fabrics Industry (INDA) Standard Test Method Committee⁵ for considerations.

The samples tested included a conventional aramid needlefelt without acid-resistant treatment, an ePTFE membrane aramid felt with acid-resistant treatment and finally, the AMAZON filter bag media. A total of 18 specimens from each media type were selected. The samples were subjected to repeated cycles of acid attack and drying. The samples were soaked in a 1N H₂SO₄ solution for 5 minutes then dried at 204°C (400°F) for 5 minutes. At the end of each cycle, 2 samples were tested for tensile strength using a testing machine suitable for ASTM D 5035-95. The cycles were repeated to measure the degradation of strength resulting from repeated exposure to acid and temperature.

The test results are shown in Figure 2. The data shows that the unique acid-resistant treatment of the AMAZON filter bags significantly reduces the impact of hydrolysis relative to the other samples tested. The conventional felt without an acid-resistant treatment was destroyed by the sixth cycle. On the other hand, the AMAZON filter bag retained almost 85% of the original strength through the sixth cycle. After the first cycle, all samples exhibited visual and physical changes. After being subjected to hydrolysis attack, the aramid felt turned brownish and became much more stiff and friable. The extent of discoloration and brittleness depended on the number of cycles to which the sample was exposed. In fact, after the sixth cycle, the conventional aramid sample was so brittle that it could not be handled without damage.

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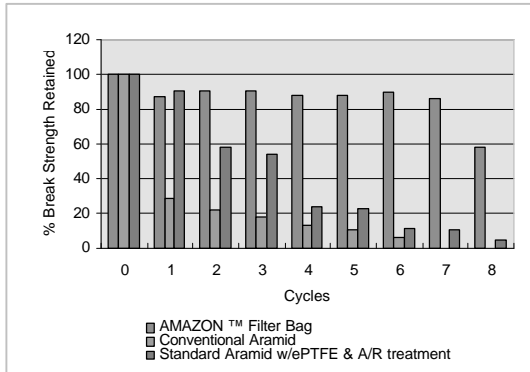


Figure 2: Strength Retention After Acid Cycling (14 oz/yd² needlefelt)

In actual baghouse applications, filter media which has been subjected to hydrolysis can cause baghouse operational problems. Stiff filter media does not release dust cake as well as the more flexible, newly installed material. The stiff felt is more prone to “splitting.” This splitting is usually seen in the vertical direction and is the result of the flexing action of the bag during cleaning. These splits allow dust to pass directly through the filter resulting in higher emissions and backside blinding of the filter. Also, this stiff material does not release dust cake buildup as effectively.

Field tests performed over the past year have confirmed the improved chemical resistance of the AMAZON filter bag. At one U.S. producer of alumina, the new aramid felt increased filter bag life in the spray dryer from 9 to 12 months (30%). This is a difficult application because the temperature is close to 150°C (300°F) and the gas stream contains moisture and acids. Previously, this collector had used P-84 polyimide and NOMEX® aramid needlefelt bags. The NOMEX outperformed the P-84, but the

filter life was still not acceptable. To improve baghouse operations at the facility, filter bag life had to be increased. The AMAZON filters met this requirement and achieved 30% longer life. The increased performance is attributed to the filter’s increased hydrolysis resistance.

Another test at a silica producer showed the new filter bags were superior to RYTON® polyphenylene sulfide (PPS) fiber felts. In this spray dryer, the temperature was greater than 150°C (300°F) and the gas stream contained sulfuric acid. After only 10 months, the oxygen and acid present in the gas stream degraded the RYTON PPS filter bags. AMAZON filter bags were installed and as of January 2000, filter life was approaching 18 months.

Dimensional Stability of Backing Material

For any filter bag installation, proper long-term bag-to-cage fit is important. When a membrane is laminated to a backing material substrate, it is important that the two have similar dimensional stability. If the backing material stretches too much, it can cause damage to the membrane. Factors influencing the dimensional stability of the backing substrate include fabric or felt construction, temperature, moisture, and the number of cleaning cycles the filter experiences.

AMAZON filter bags incorporate a state-of-the-art felting technique to create a felt that is stronger and more dimensionally stable. These improvements result from consistent fiber entanglement during the needling operation and a strong scrim design. As the data in Table 2 shows, AMAZON filters have better initial strength and lower elongation than other typical aramid felts.

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	AMAZON Filter Bag Media	Conventional Aramid Felt
Weight	475 gm/m ² (14 oz/yd ²)	475 gm/m ² (14 oz/yd ²)
Breaking Strength (ASTM D-5035-95)		
Machine Direction	127 kg/5 cm (280 lb./2 in)	66.4 kg/5 cm (146 lb/2 in)
Cross-Machine Direction	204 kg/5 cm (450 lb./2 in)	121.4 kg/5 cm (267 lb/2 in)
Elongation at 50 lb. (ASTM D-5035-95)		
Machine Direction	2.3%	5.3 %
Cross-Machine Direction	4.6%	7.9%
Mullen Burst (ASTM D-3786-87)	4,825 kilopascals (700 psi)	3,446 kilopascals (500 psi)

Table 2: Aramid Product Comparison

The increased strength and lower elongation of the new felt results in enhanced dimensional stability. In a pulse jet filter bag, an important consideration is how well the filter fits the cage. If the bag is too large or stretches excessively in use, there will be increased bag movement on the cage. For filter bags, the most important dimension to control is the bag circumference (cross-machine direction). Looseness in the circumference causes mechanical damage to the felt. Visually, this damage looks like vertical cracks. As shown in Table 2, the AMAZON filter bag has significantly lower elongation in the cross-machine direction than the conventional aramid felt (4.6% vs. 7.9%). Therefore, AMAZON filter bag media can withstand mechanical stress better and provide better support than conventional aramid felts.

Filtration Efficiency Properties

Industrial baghouse filtration is generally classified into two types: a) depth filtration (conventional) and b) surface filtration (membrane). Depth filtration relies on a

two-stage process to achieve maximum filtration effectiveness. First, dust is built up inside the felt. Eventually, a dust cake forms on top of the filter surface. Dust cake buildup on the filter surface can have a significant impact on the dust cake resistance coefficient (K_2) and hence, the overall pressure drop across the filter media. An investigation of the factors influencing dust cake buildup and pressure drop for several fine dusts is presented by Cheng et al.⁶

Conventional filtration is generally acceptable for collecting large particles (>5 μm); however, it is not as effective for smaller, submicron-sized particles. Problems associated with conventional filters include: higher emissions, higher pressure differential (ΔP) across the filter due to clogging of the felt, and “puffing” just after the cleaning cycle. Puffing occurs when particles are dislodged from the felt during cleaning, resulting in a temporary increase in emissions.

W. L. Gore & Associates first introduced surface filtration for industrial processes in 1973. To achieve filtration efficiency and improved dust cake release, a high efficiency, microporous ePTFE membrane was laminated to standard filtration needlefelts and fabrics. The patented filtration products are sold under the “GORE-TEX®”tradename.

The revolutionary aspect of the invention is that the membrane serves as the primary filtration layer. With surface filtration, there is no need to allow the particulate matter (PM) to build up inside the felt. In the new composites utilizing ePTFE membrane, the felt serves as a support for the membrane.

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There are several benefits associated with surface filtration including: 1) increased efficiency in the submicron particle size range, 2) lower baghouse pressure drop from improved dust cake release, and 3) improved product quality and process reliability due to a more stable pressure drop.

Figure 3 shows a comparison of conventional and membrane filtration. The picture on the right shows a conventional felt filter. The dust particles within the cross-section of the felt are visible. Over time, this dust buildup causes higher pressure drop across the tubesheet, affects the filter's efficiency, and ultimately reduces process airflow.

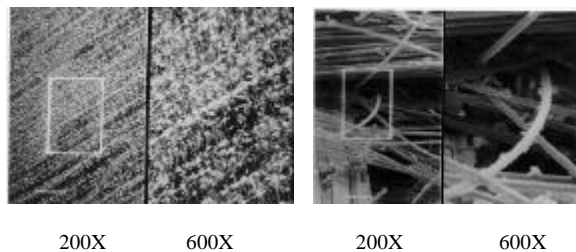


Figure 3: Membrane Filtration vs. Non-Membrane Filtration

The photograph on the left shows an ePTFE membrane filter. The particles remain on the surface of the membrane. The ePTFE membrane is a nonstick surface that allows for easy cake release while achieving greater filtration efficiency for all particle sizes.

A comparison of filtration efficiencies for conventional media vs. ePTFE membrane is shown in Table 3. These efficiencies were measured using a TSI, Inc., AFT 8160 Automated Filter Tester. There is a significant improvement in efficiency for the membrane filter. Although ePTFE membrane filtration is a substantial improvement over conventional filtration,

recent advances have been made which further enhance the filtration efficiency of ePTFE membranes.

Particle Size (μm)	ePTFE Membrane Aramid Felt	Conventional Aramid Felt
0.03	93.99	75.39
0.04	92.59	68.83
0.05	91.28	62.58
0.07	89.46	54.68
0.1	89.48	43.09
0.15	89.27	35.22
0.2	90.25	34.04
0.3	94.42	23.07

Table 3: Filtration efficiency (count basis, face velocity = 5.0 cm/sec): comparison of standard ePTFE membrane composite vs. conventional aramid felt

Membrane Durability

One of the most important characteristics of membrane filtration is durability. Durability can be defined as the ability of the membrane to resist mechanical damage over time. In use, a filter bag is subjected to mechanical stresses as it repeatedly folds over the support cage during cleaning. These stresses break some of the bonds in the membrane's unique node and fibril structure and cracks develop. The number and severity of these cracks depend upon a number of factors, including frequency of cleaning pulses, amount of pulse pressure used, and filter life. While the dynamics of membrane cracking are not yet completely known, it is expected that membrane damage will increase with filter bag life. Figure 4 shows a photomicrograph of a commercially available aramid felt with ePTFE membrane. The photomicrograph on the left was taken at 50x magnification, and the photomicrograph on the right is a close-up of the same crack taken at 200x magnification. The filter from which this sample was obtained had been installed in a

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silica spray dryer baghouse. The membrane cracks are easily seen. Damage to the membrane decreases the filter's ability to efficiently capture particulate and release dust cake. As a result, filter performance degrades and causes increased emissions, higher pressure drop, increased dust-to-fiber mechanical wear, and ultimately, shorter overall bag life.

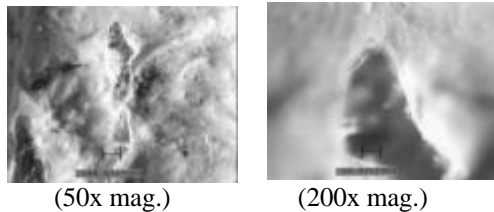


Figure 4: Photographs showing membrane cracking on aramid felt backer material after 16 months of service

As mentioned earlier, the amount of membrane damage and the effect on baghouse operation varies greatly. However, new membrane technology developments can significantly reduce the formation of these cracks.

New, Patented Membrane

A new generation of patented ePTFE membranes has been developed. When membranes for industrial filtration were first introduced, it was determined that enhancements to membrane durability were needed. These early membranes were subject to damage prior to use from handling and installation. Once in service, they were also subject to damage resulting from flexing during cleaning pulses. To make a membrane stronger, the typical response was to make the membrane thicker, but this also reduced permeability. The end result was a composite that traded off permeability for strength.

W. L. Gore & Associates has developed a new family of ePTFE membranes which possesses a unique combination of strength and permeability. These membranes have: 1) improved efficiency, 2) higher strength-to-permeability ratio, and 3) enhanced membrane durability.

Improved Efficiency: Table 4 shows the initial efficiencies of unused samples of a commercially available aramid felt/ePTFE membrane composite and the improved AMAZON filter bag composite using the new membrane. While these tests cannot adequately reflect true operational performance, they are useful to compare the performance of different filter media.

Particle Size (µm)	PTFE Membrane Aramid Felt	AMAZON Filter Bags with New Membrane
0.03	93.99	95.54
0.04	92.59	94.24
0.05	91.28	93.56
0.07	89.46	92.07
0.1	89.48	92.15
0.15	89.27	91.17
0.2	90.25	95.94
0.3	94.42	97.39

Table 4: Filtration efficiency (count basis, face velocity = 5.0 cm/sec): comparison of standard ePTFE membrane composite vs. AMAZON filter bag media with new membrane

Another method for determining efficiency in use is to evaluate membrane cracking of used filters. The more a membrane cracks, the more dust can penetrate the filter media. It is difficult to gather in-field efficiency data, but it is known that increased cracking can reduce filtration efficiency. The reduction in membrane cracking with the new membranes will be discussed later.

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Enhanced Membrane Durability: The new series of membranes represents a significant development in providing higher airflow and stronger membranes. Figure 5 shows the membrane permeability vs. strength of several membrane groups. Series A represents some of the earliest membranes developed for industrial filtration, while series D shows some of the newest membranes. Note that the new membranes have more than double the strength of the oldest membranes at the same permeability.

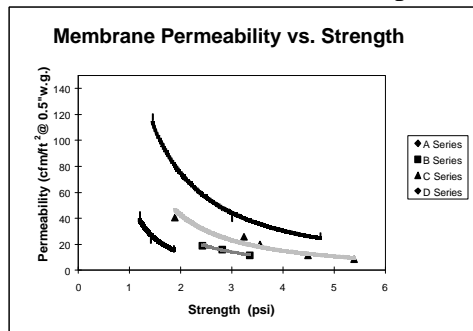


Figure 5: Comparison of permeability vs. strength for ePTFE membranes

With the new membranes, filters can be designed with the optimum combination of high permeability and membrane strength.

CASE HISTORY

While laboratory research can provide useful data for development purposes, the new aramid felt/ePTFE membrane composite must be proven in actual field applications. One such application was found at a company in the U.S. in which a component in their manufacturing process is a powder product. A baghouse is used to control the fine particulate emitted from the process.

For a number of years, the filters used were commercially available aramid felt/ePTFE membrane filter bags. Filter life was limited

to 12 months. Once the pressure drop exceeded 10 inches w.g., the bags had to be removed. A filter bag analysis revealed the bags were in good mechanical shape but the filter cross-section was filled with dust. A laboratory examination revealed that over time, the membrane on the filter bags had become damaged, allowing dust to penetrate the felt.

In October 1998, four AMAZON filter bags with the new membrane and four aramid bags with a previous generation membrane were installed. The bags were pulled out for analysis after 6 months and 9 months of service. The analysis showed that the standard product had developed membrane cracking at 6 months and more after 9 months. The AMAZON filter bags with the new membrane revealed virtually no cracking at 6 months and significantly less than the standard product after 9 months.

Photographs of these samples after 6 and 9 months are shown in Figure 6. Due to the opaqueness of the aramid felt, backlighting of the samples was used. The photographs show the backside of the filter. The filters on the left are the standard product and the filters on the right are the AMAZON filter bags with new membrane. The dark spots show membrane damage where the dust penetrated the filter. Note the significant reduction in bleed-through seen on the AMAZON filter bags with the new membrane.

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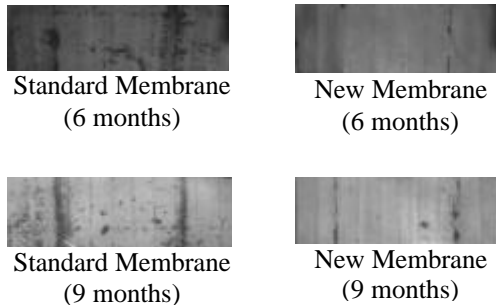


Figure 6: Photographs of the backside of used filters showing dust bleed-through from membrane damage

Based on the success of the trial, a full baghouse of AMAZON filter bags was ordered. Results of this full baghouse trial will be reported at a later date.

CONCLUSION

The pulse jet style dust collector has become the predominant technology for industrial filtration. Because the pulse jet relies on high energy cleaning of the filter element, the proper selection of a filter media is crucial to the optimal operation of the system. Today's baghouses process more air (higher air-to-cloth) and are cleaned more frequently. At the same time, the filter media is expected to last longer. Thus, filter suppliers must respond by developing better filter media.

The AMAZON filter bags discussed in this paper are an example of the successful combination of new membrane technology and state-of-the-art felt substrates. These new filters offer superior filtration performance by providing the longest life, most durably efficient service. The benefits of these new filters include improved filtration efficiency to meet emissions for better filtration efficiency, longer bag life, and less process downtime. All of these benefits translate into operational cost savings.

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