Microfiltration with wet-lay flash-spun polyolefin pulp filter media

Hyun S. Lim, G. Paul S. Kochar, Carl K. McMillin, and John O. Molter

ABSTRACT: A capturing efficiency greater than 95% for 1-μm particles and high dirt holding capacity were achieved with wet-lay sheets made from refined, flash-spun polyethylene fiber pulp. Its superior filtration performance exceeded that of melt-blown media and wet-lay sheets made from competitive synthetic polyolefin pulp. The unique fiber media has been successfully utilized in air filtration applications where removal of fine airborne particles is required to improve indoor air quality.

KEYWORDS: Development, filters, filtration, flash dried pulps, media, performance, polyolefins, pulps, sheets.

Tyvek® spunbonded olefin has been produced by the DuPont Co. for more than 20 years and has been used in a wide range of applications, such as graphics, packaging, envelopes, apparel, construction, and filtration, which utilize its unique high tensile, tear, opacity, and microbial barrier properties. However, use of Tyvek as a filtration media has been limited because of its low permeability (about 25 s/100 cc Gurley Hill, <1 $ft^3/min/ft^2$ Frazier air permeability).

In 1988, we introduced a new style of Tyvek (T-980) developed specifically for filtration by a new bonding process used to engineer structures with air permeabilities of 5 s/100 cc Gurley Hill or Frazier air permeabilities of about 1 $ft^3/min/ft^2$. This product is used successfully in automatic pressure filter (APF) machines for removal of heavy metals from waste waters to meet strict limits set by the U.S. Environmental Protection Agency (EPA) National Pollutants Discharge Elimination System (NPDES).[1]

In April 1990, T-980 Tyvek on an Oberlin APF machine was evaluated under the EPA Superfund Innovative Technology Evaluation Agency Program at the Palmerton Zinc Superfund site in Palmerton, PA. The groundwater was contaminated primarily with high levels of zinc (400–500 mg/L) and trace levels of cadmium (1 mg/L). A 99.5% removal efficiency was achieved for zinc and total suspended solids (TSS). The filtrate met the applicable NPDES permit limits established for disposal of metals and TSS into a local waterway. The filter cake passed the paint filter liquids extraction and leaching procedures toxicity tests which show that the filter cake can be disposed of safely in a nonhazardous waste landfill.[2]

However, Tyvek continuous plexifilament bonded sheet products do not have sufficiently high air flow rates for use in some important filtration applications. The sheet structure can be tailored to increase air flow rates by changing the web formation process. This paper reviews the development of a new wet-lay sheet product from cut and refined flash-spun polyethylene fiber pulp to give some unique filter media with Frazier air permeabilities of from 6 $ft^3/min/ft^2$ to 12 $ft^3/min/ft^2$ and with average pore sizes ranging from 7 μm to 10 μm.

Nonwoven filter media comparison and selection

Three basic, direct spinning technologies exist in the nonwovens industry to produce filter media: melt spinning, melt blowing, and flash spinning.

Melt spinning involves extruding filaments through spin-erect orifices followed by air quenching and by drawing the fibers through aspirator jets by concurrent air streams. The descending fibers are electrically charged to separate them and pin them down in a completely random configuration onto a moving belt under which a suction box is placed. These fibers are relatively coarse because they are limited

[1] Lim, H. S. and Mayer, E., TAPPI 1990 Nonwovens Conference Proceedings, TAPPI PRESS, Atlanta, p. 383.

[2] "DuPont/Oberlin Microfiltration Technology," EPA Applications Analysis Report, EPA Contract No. 68-CO-0047, Department, Laurel Run, Chestnut Plaza, January 1991.

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I. Properties of polyethylene pulps

Property	Pulplus®	Competing polyethylene
Kajaani length, mm	0.9–1.0	0.6–1.2
Kajaani coarseness, mg/m	0.14–0.18	0.7–1.5
CSF, mL	480–520	620–765
Zero span strength, psi	22–25	6–9

II. Physical properties

Property	Filter media		
Style	S-1042	T-980	Hysurf
Basis weight, oz/yd^2	1.25	0.9	2.0
Thickness, mils	5.2	4.0	9.5
Elmendorf tear (MD/CD), lb	0.7/0.7	0.2/0.2	0.2/0.2
Grab tensile (MD/CD), lb	40/57	42/25	35/17
Mullen burst, psi	76	91	40

III. Permeability properties

Property	Filter media		
Style	S-1042B	T-980	Hysurf
Gurley Hill porosity, s/100 cc	11	5	<1
Frazier air permeability, ft^3/min/ft^2	<1	<1	6–12
Air flow rate at 10 psi, L/min/cm^2	5.8	13.7	50
Water flow rate at 10 psi, L/min/cm^2	25	93	310
Retention efficiency at 10 ft/min, % 1.1 μm latex spheres	93.9	96.4	97
Coulter pore size, μm			
Maximum	11.7	10.7	12.3
Minimum	2.5	1.9	4.0
Mean	3.4	2.8	6.7

by the capillary size of the spin-erect orifice and subsequent drawing.

The melt-blowing process, pioneered by the Naval Research Laboratory and refined and licensed for commercial use by the Exxon Corp., gives very fine micro-denier fibers by extruding molten polymer through spin-erect orifices and fibrillating the extruded fibers by high-temperature and high-velocity air streams. The melt-blown fibers are formed into a sheet on a moving belt equipped with a suction box. These fibers have lower strength than melt-spun fibers and are often used in composites with stronger fiber webs. Although surface area of melt-blown fibers per unit weight is larger than that of melt-spun fibers, it is smaller than that of flash-spun plexifilamentary fibrils.

The high surface area of flash-spun fibers results from interval voids in the fibrils created by rupturing solvent vapor globules within the polymer solution during the flash-spinning process. Flash spinning involves decompression of pure solvent droplets and highly saturated polymer and solvent mixtures through a spin orifice. The highly oriented continuous plexifilamentary fiber network is electrically charged and collected on a moving belt as a consolidated sheet structure. The micro-denier oriented fiber morphology contributes to high filtration efficiency and good sheet tensile and tear strength after bonding.

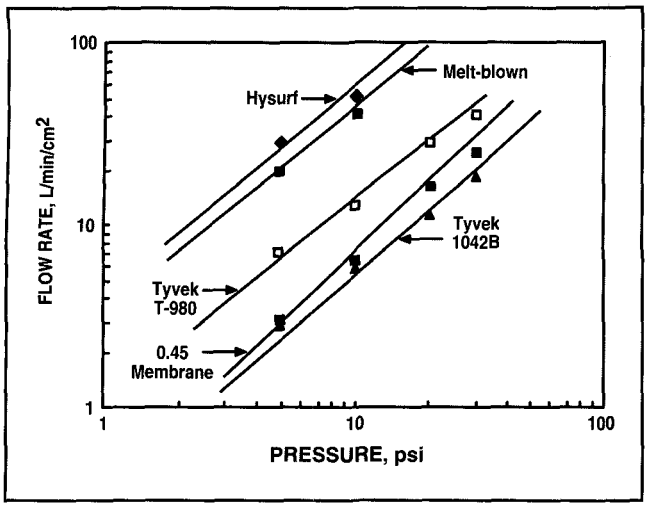
Proper selection of filter media is one of the most important factors in determining the performance characteristics of a filter. The criteria for selecting the optimum filter media are: fluid permeability rate vs. pressure, filtration efficiency vs. particle size, filtration capacity or filter life, and overall filtration cost or economics.

Hysurf™ as a filter media

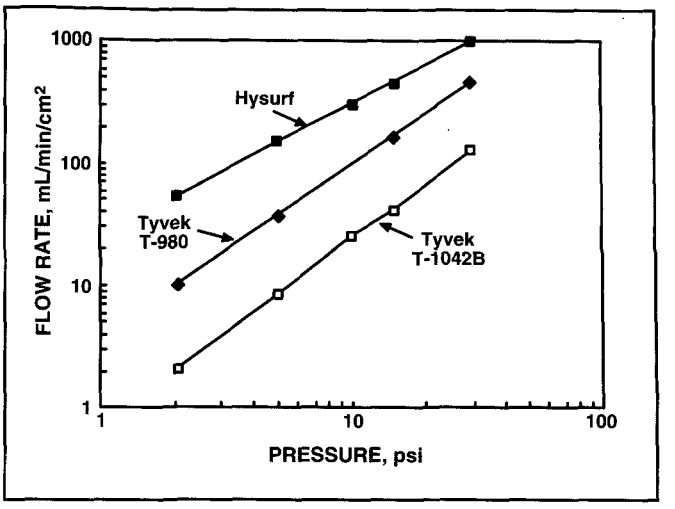
Flash-spun, high-density polyethylene fibers, which are very fine and strong, provide a source for short fibers and pulp that can be used to prepare wet-lay sheet products with good strength, high surface areas, and relatively high porosities. After cutting flash-spun polyethylene fibers into short lengths and further refining into pulp for wet-lay sheet formation, the pulp surface area is about four to six times that of kraft cellulosic pulp fibers. The high surface area is related to the fineness of the flash-spun fibers. Properties of refined flash-spun polyethylene pulp are compared with those of a competitive polyethylene pulp in **Table I**.

Flash-spun polyethylene pulp, as measured by Kajaani coarseness, is about 5–10 times finer than the competitive polyethylene pulp. This leads

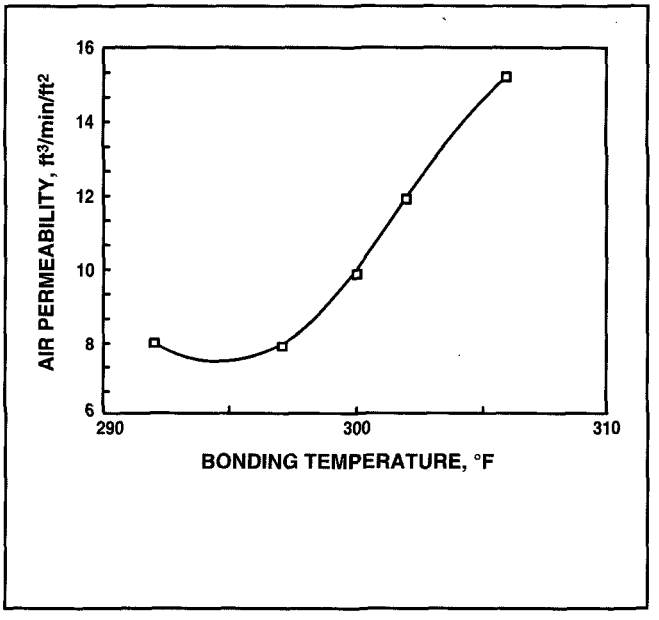
1. Air flow rate vs. pressure for competitive media



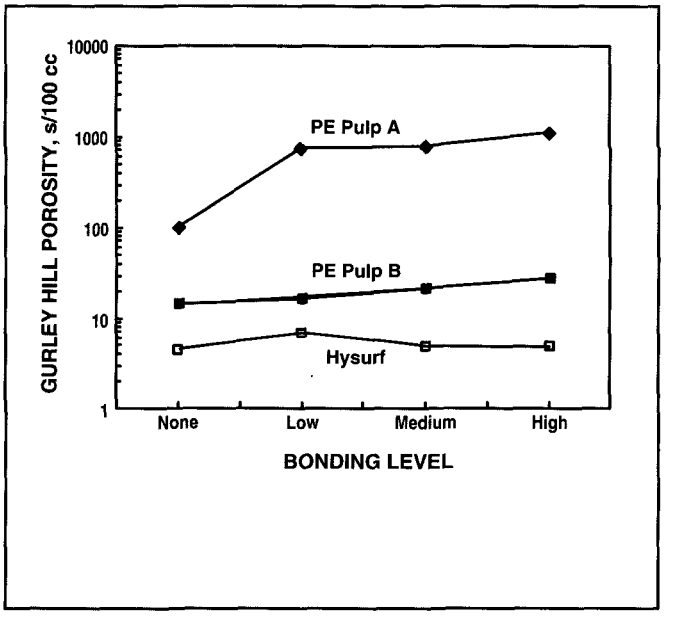
2. Water flow rate vs. pressure of Tyvek filter media



3. Frazier vs. bonding temperature for Hysurf



4. Permeability vs. bonding level for competitive pulps



to a tighter fiber web network, indicated by a 25–30% lower CSF liquid volume flow rate. The significantly higher zero-span strength of flash-spun pulp is a function of the unique, high fiber orientation of flash-spinning technology.

Web formation

The flash-spun polyethylene pulp is formed on a flat-wire fourdrinier paper machine to give wet-lay papers which, after drying, are from 1.5 oz/yard² to 3.5 oz/yard² in weight with Frazier air permeabilities of from 2 ft³/min/ft² to 6 ft³/min/ft². The wet-lay product is thermally bonded under varying conditions to give rolls of the final filtration media, which may be slit to required widths and packaged to meet customer needs. Products with varying porosities, pore sizes, and filtration characteristics can be made by adding synthetic or natural fibers to the flash-spun polyethylene pulp in the liquid furnish.

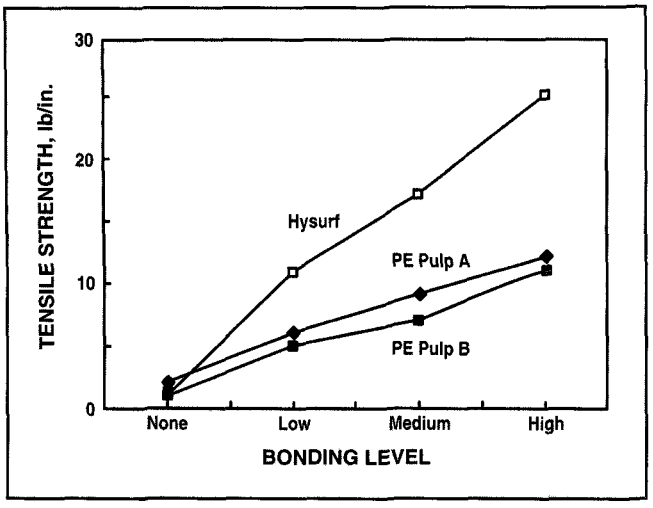
Bonded sheet properties

The physical and permeability properties of a bonded Hysurf sheet is compared with two bonded Tyvek products in **Tables II and III.**

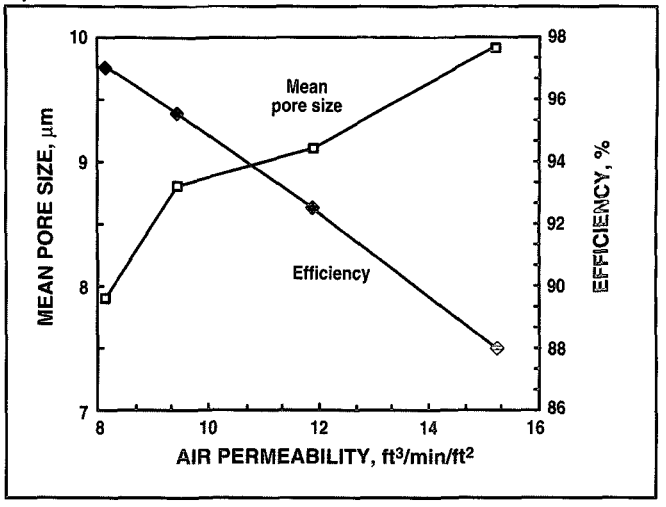
Due to discrete 1-mm fiber lengths, the bonded wet-lay sheet is significantly lower in tensile and tear strength than the spunbonded plexifilament sheet structures, but it offers much higher air and water permeabilities.

Figure 1 shows air flow rates versus pressure for a 2- oz/yard² Hysurf sheet versus two Tyvek products, a 0.45-μm rated membrane sheet and a 1-μm rated melt-blown product. Water flow rates versus pressure are shown in **Fig. 2** for similar products. A much greater per-

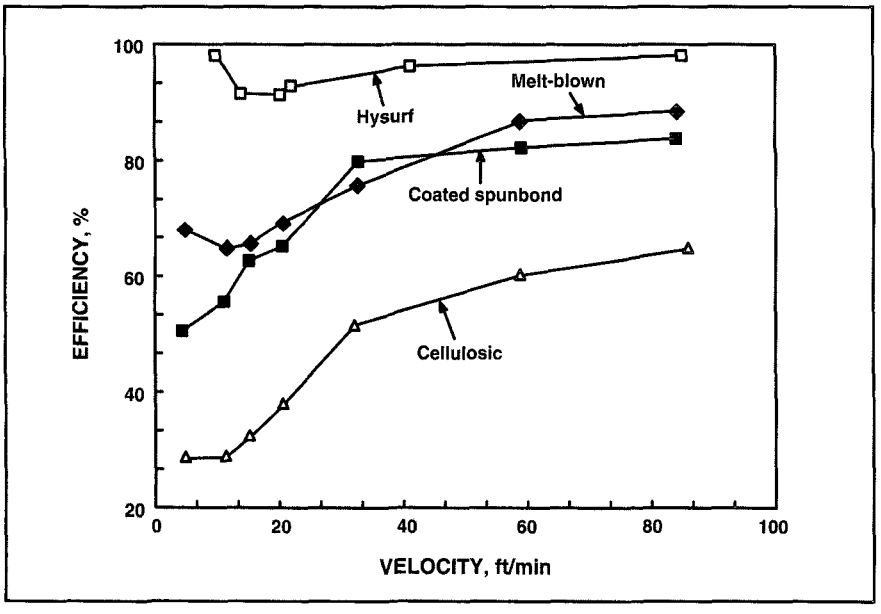
5. Tensile vs. bonding level for competitive pulps



6. American Society for Testing and Materials F 1215-89 filter test on Hysurf sheet



7. Micron filtration efficiency vs. velocity



meability is achieved with the Hysurf sheet at a given pressure than with the spun-bonded Tyvek products or with the microporous membrane. The permeability of the Hysurf sheet is comparable to that of the excellent permeability of the melt-blown filter media.

Figure 3 shows how bonding temperature affects Frazier air permeability of Hysurf sheet products. Air permeability varies from about 4 $ft^3/min/ft^2$ to about 15 $ft^3/min/ft^2$ with increasing bonding temperature. Due to high orientation in the flash-spun polyethylene fibers, the individual fibers shrink more at higher temperatures, resulting in a more open sheet structure. By comparing Gurley Hill porosity of a Hysurf sheet with the porosity of competitive polyolefin pulp sheets bonded at increasing levels (**Fig. 4**), one sees an increase in Hysurf sheet porosity and a decrease in porosity for competitive pulps. Also, there is a larger effect of bonding temperature on tensile strength for the Hysurf sheet than for the competitive pulp sheets shown in **Fig. 5**. We believe that the higher fiber orientation in the Hysurf sheet versus other pulp sheets accounts for the increased tensile strength of highly bonded products.

Based on a challenge test with 1-μm polystyrene latex spheres, retention efficiency of the Hysurf sheet is comparable to that of Tyvek products (97% vs. 94–96%, Table III). Further improvements in retention efficiencies for submicron particles may be possible with a Hysurf sheet by coating or calendering.

The retention efficiency of a 2-oz/$yard^2$ bonded Hysurf sheet versus mean pore size and Frazier air permeability is shown in **Fig. 6**. The retention efficiency with 1-μm latex spheres at 60 ft/min face velocity varies from 88% to 97% for sheets with mean pore values from 8 μm to 10 μm and with Frazier air permeabilities of from 15 $ft^3/min/ft^2$ to 8 $ft^3/min/ft^2$. As expected, there is an inverse relationship between the mean pore size of the media with retention efficiency.

A high retention efficiency is achieved as a result of smaller mean pore size at a lower Frazier permeability. Particle retention efficiencies of the Hysurf sheet are compared with those of other sheet products at face velocities of 5 ft/min to 90 ft/min in **Fig. 7**. A higher retention of 1-μm particles is achieved by the Hysurf sheet at all air velocities tested versus retention by the competitive media. This con-

firms that the fineness and high orientation of fibers inherited from the flash-spinning technology are important factors in determining high particle retention characteristics versus melt-blown, melt-spun, and wet-lay cellulosic media.

The smooth, low-friction surface of the Hysurf sheet together with its good tensile strength contribute to ease of filter cake release, and the asymmetric structure contributes to an increase in filter capacity or life.

Potential market opportunities

The relatively high air permeabilities of Hysurf sheet products, combined with high retention efficiencies and high wet and dry strength, suggest superior performance in air filters used to improve indoor air quality in industrial, home, office, school, and hospital facilities. Hysurf also has the potential for use in respirator air filters and in high-efficiency particulate air filters for clean rooms. The high liquid filtration rates for Hysurf products suggest filtration uses in separation of solid particulate products such as specialty chemicals and pharmaceutical products.

Conclusion

Wet-lay sheet products made with flash-spun high-density polyethylene fiber, cut and refined into pulp, offer new and improved filter media for air and liquid filtration markets. The ability to tailor permeability with controlled porosity is demonstrated by capitalizing on the unique values in fineness and high fiber orientation inherited from flash-spinning technology. TJ

Hysurf® is a DuPont registered trademark for flash-spun polyolefin pulp paper.

Tyvek® is a DuPont registered trademark for spunbonded olefin products.

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