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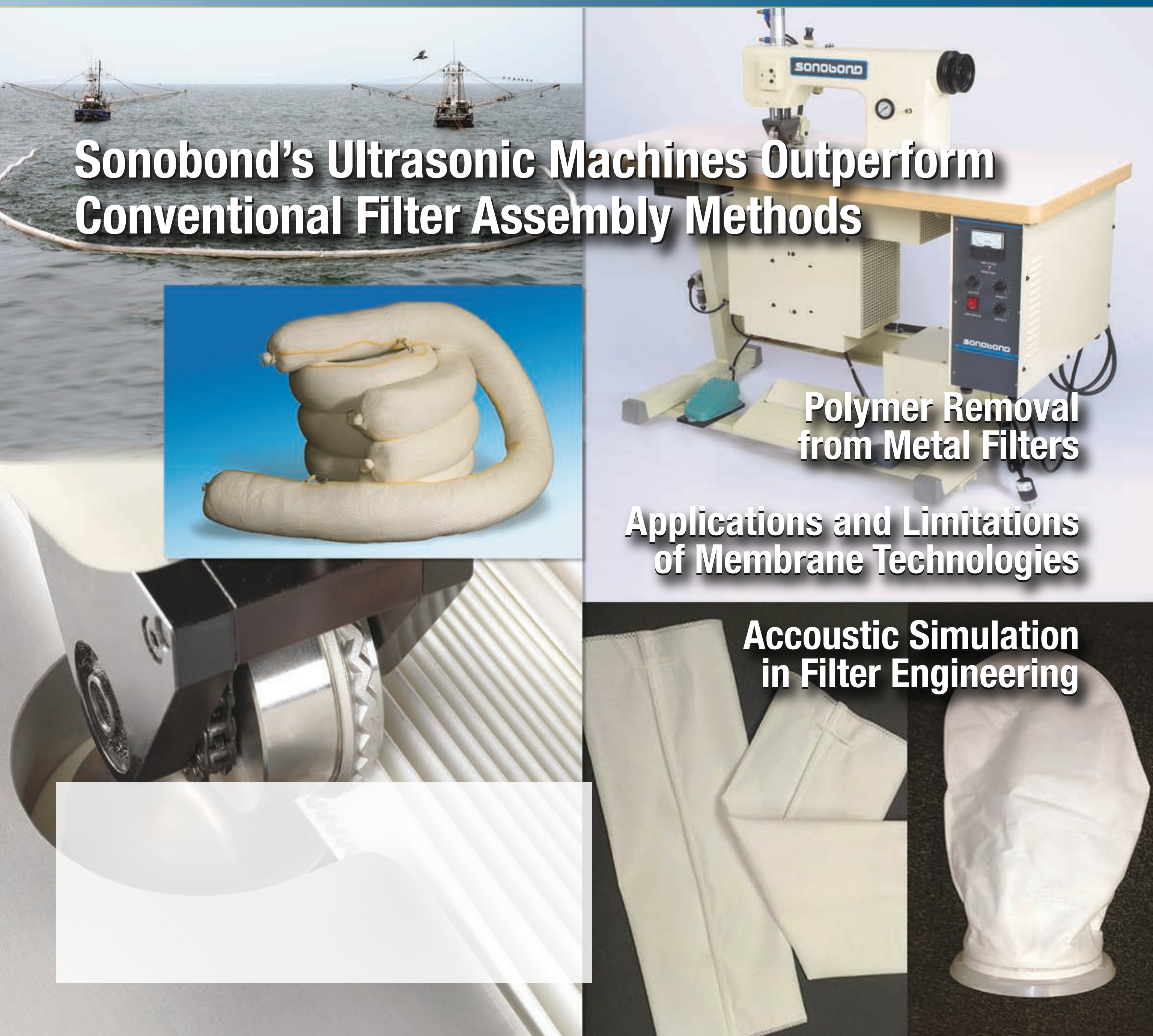


Sonobond's Ultrasonic Machines Outperform Conventional Filter Assembly Methods

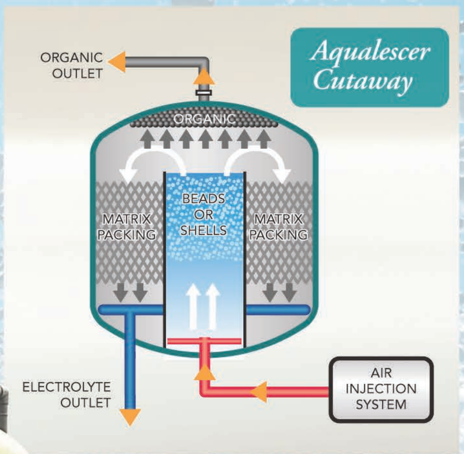
Polymer Removal from Metal Filters

Applications and Limitations of Membrane Technologies

Accoustic Simulation in Filter Engineering

Coalesce Your Way to Lower Costs with AQUALESCER™

by SpinTek



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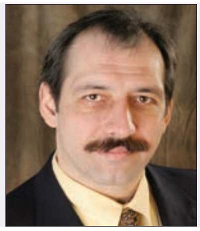

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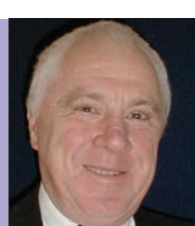

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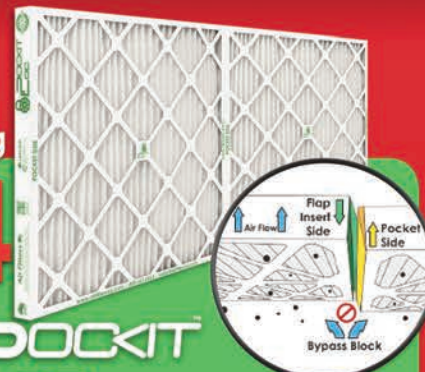

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AFS Attendance Reaches Post-Recession Record at Fall Conference

Attendence at the AFS Fall Conference was more than double that of last year's, signaling that perhaps the long recession in the USA is over and the industry is upbeat about the future.

The 2014 American Filtration & Separations Society Fall Conference realized double attendance compared to the 2013 event covering the topic of filtration media. This is a positive sign the recession is drifting into the rear-view mirror and the industry is beginning to look forward to the future with a positive embrace. The 2014 Conference titled "Next Generation Filtration Media…Embracing Challenges" was held at the Hilton Rosemont at Chicago O'Hare Airport, October 13-16. Conference co-chairs were Andrew Goodby, Ahlstrom Filtration, LLC; Sebastian Stahl, DuPont; and Sneha Swaminathan, Hollingsworth & Vose.

The conference began with broad contingent of both domestic and foreign attendees taking part in eight in-depth courses, all taught by industry specialists at its half- and full-day short courses. The AFS has been offering these courses on various filtration, separation and coalescing subjects since its inception in 1988. This fall's offerings were (1) Introduction to Liquid Filtration, (2) Filter Media Design for Liquid Filtration Applications' (3) Filtration, Separation & Coalescing Media

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Use and Markets; (4) Ultrafiltration Membranes; (5) Liquid Filtration Testing Basics; (6) Microfiltration Membranes; (7) Nanofiber Technology In Filtration; and (8) Advanced Engine Filtration. Each AFS course provides CEU credits. As an added conference activity, AFS offered two tours; one at the University of Illinois (Chicago) Filtration Facility and another following the conference at the Stickney Water Reclamation Facility with transportation provided for those attending.

KEYNOTERS

The conference introductory plenary speaker was VP Technology and Chief Technology Officer, Dr. John Fitzgerald, from Hollingsworth & Vose. The AFS luncheon speakers were the National University of Singapore, Director of Center of Nanofibers and Nanotechnology, Dr. Seeram Ramakrishna and Darrell Reneker, University of Akron, who spoke on the topic Nanofiber Morphology of PVDF.

NEW AFS CONFERENCE TOPICS

This fall's conference once again consisted of three concurrent tracks with 72 presentations including a specific AFS on-going plan to offer at least one complete track on Air Filtration, not limited to this conference but for future conferences as well, in addition to its historical Liquid Filtration Separation and Coalescing tracks. Beginning in the spring of 2015 in Charlotte, N.C. and future spring and fall events, the AFS will also add, in addition, one more new track – the Theoretical, Applied Science and Design track specifically for those who have specific interests in academic and/or industrial basic research, applied science and design subjects.

The leadership of the AFS has felt for some time that it needs additional tracks based on requests of varied tailored interests by its members and is responding accordingly with Air Filtration and the Theoretical, Applied Science and Design tracks to start. As interest grows in one or more of these or other areas and there appears to be a large enough and growing demand, the society will add new subjects and/or multiple tracks on related subjects at both its future spring and fall conferences. The society anticipates growth on a number of fronts in future years and is developing the needed infrastructure at this time in anticipation of evolution and expansion of the Society.

CORPORATE SPONSORS

At the Corporate Sponsors meeting, a review of existing and new programs were revealed, including the announcement of booths at future conferences beginning modestly with a limited number of booths at the 2015 AFS Power Generation Conference in Charlotte, N.C. Immediately prior to the recent business recession, the AFS typically had 70-80 booths at its events and well over 120 booths, just shy of 500 presentations when it hosted the World Filtration Congress in 2004 in New Orleans. With continuing growth of Corporate Sponsorships and the addition of a number of new benefits, the leadership of the AFS feels it's time to begin once again, in a modest way, to offer booths as well as continuing to offer tabletop locations for those sponsors and non-sponsors who wish to have tabletops. For the 2016 spring Houston conference, which will focus on oil, gas and chemical industry filtration needs, the AFS is also exploring the possibly of much larger displays in addition to booths as the conference organizer has had substantial interest in even larger exhibits.

The AFS is fortunate to have a strong loyal industry following and leadership of many dedicated companies and individual volunteers. The Society is now managed by a small, but highly focused management company, XMi in Nashville, and administered by Lyn Sholl and Betsy Hilt. Industry volunteers provide AFS leadership on the executive committee, board of directors, and on fifteen committees at the local chapter level. The society is growing and continues to seek assistance in many ways, so people who have some time or interest and want to feel part of something important can contact either Lyn (Lyn@afssociety.org) or Betsy (betsy@afssociety.org), or call 615-250-7792.

The American Filtration & Separations Society is the largest Filtration Society in the world and the principal educator of the industry.

For more information visit:
www.afssociety.org

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Sonobond's Ultrasonic Machines Outperform Conventional Filter Assembly Methods as Synthetic Blends Gain in Usage

Synthetic blends used in filter manufacture are ideally suited for ultrasonic assembly provided by Sononbond's equipment. The bonding process takes only seconds, requires a minimal amount of material at the seam and creates a strong molecular seal that's impervious to moisture and eliminates stitch holes, glue gaps, fraying and unraveling.

As synthetic blends continue to penetrate the filtration market, replacing paper and woven materials, the ultrasonic bonding capabilities of Sonobond's ultrasonic assembly equipment have become even more essential to effective and reliable filter assembly.

THE GROWTH OF SYNTHETIC BLENDS

Woven textiles were initially the first choice for many filtration industry sectors. But by the 1970s, synthetic materials – including blends with polyester, polypropylene, and nylon – and felted filter material proved even more effective for air and liquid filtration products and ideal for ultrasonic assembly.

Today, these materials are gaining in popularity for filtration media used for coolant, vacuum cleaner, HVAC, and liquid applications. New and improved synthetic blends are increasingly used in filters incorporating nanofibers for better dust collection and engine air-intake applications. Plus, their use continues to expand as manufacturers demand energy saving, cost effective, light weight and recyclable materials with finer filtering capabilities; consumers expect better filtration of water and air; and government regulations require higher filtration standards.

ULTRASONIC FILTER ASSEMBLY

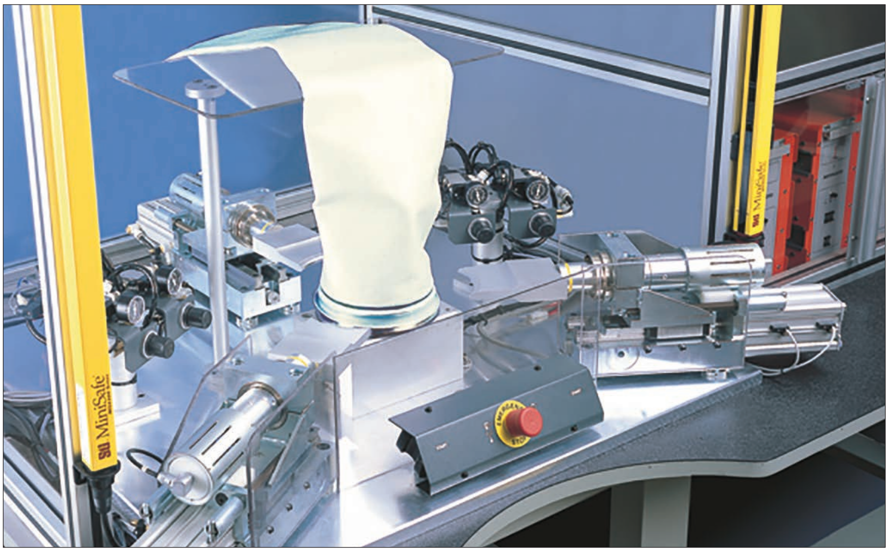
Sonobond continues to be the leading provider of ultrasonic bonding machinery, offering a reliable, well-established and environmentally friendly technology for assembling filters and filtration products. Sonobond's equipment employs ultrasonic vibrations to soften and fuse the synthetic blends and filter materials. The ultrasonic bonding process takes only seconds, requires a minimal amount of material at the seam and creates a strong molecular bond that's impervious to moisture and eliminates stitch holes, glue gaps, fraying and unraveling. In fact, Sonobond's machines are four times faster than conventional sewing machines and 10 times faster than adhesive machines.

EQUIPMENT FOR DIVERSE NEEDS

Sonobond offers a versatile line of ultrasonic bonding equipment to suit the varied assembly requirements of filtration manufacturers. All machines are easy to operate, and require little training.

ULTRASONIC SEWING MACHINES

Sonobond's ultrasonic sewing equipment – recently awarded trademark registration as SeamMaster® Ultrasonic Sewing Machines – is among the most flexible and adaptable for filter assembly. Among other applications, the machines are used for assembling air



The innovative RingMaster Filter Bag Machine ultrasonically attaches heavy felted filter media to rigid plastic rings, creating a dependable 360-degree bond in just two steps. The process takes less than 10 seconds and can produce up to 250 bags per hour for use in the petroleum, food, chemical and pharmaceutical and other industries.

Sonobond's SeamMaster Ultrasonic Sewing Machines resemble conventional sewing machines but feature a patented, continuous bonding, rotary operation where both horn and pattern wheel rotate at the same time.

filters employed in HVAC, dust collection, nuclear and bio-chemical applications; for bonding the longitudinal seams of oil containment booms, and liquid and gas filter cartridges; for creating fuel filters; and for making filtration components for commercial and military jet fuel handling.

Sonobond's SeamMaster Ultrasonic Sewing Machines resemble conventional sewing machines but feature a patented, continuous bonding, rotary operation where both horn and pattern wheel rotate at the same time to cut, trim and sew in one pass, producing an ultra-reliable seal. More than 500 standard pattern wheels are available, as well as custom designs for slitting, sealing, seaming, and embossing.

The ultrasonic sewing machine most useful for filter assembly is Sonobond's High Profile model, featuring greater clearance for hand-guided operations with tight tolerances and curves. The High Profile model also offers a special fixture for bonding pleated filters with narrow pleats; pleats wider than ½-inch can be welded without a fixture. To view a video showing the SeamMaster High Profile Ultrasonic Sewing Machine in operation visit: http://www.sonobondultrasonics.com/welders-bonders/nonwovens-textiles.

RINGMASTER FILTER BAG MACHINE

Sonobond's RingMaster™ Filter Bag Machine is designed for high-quality, high-volume assembly of heavy-duty filter bags used in a variety of sectors, including the petroleum, food, chemical and pharmaceutical industries. This innovative unit ultrasonically attaches heavy felted filter media to rigid plastic rings, creating a dependable 360-degree bond in just two steps. The process takes less than ten seconds and can produce up to 250 bags per hour. Custom tooling accommodates a variety of bag sizes and ring diameters. A video showing filter bag assembly using the RingMaster Filter Bag Machine is also available by visiting: http://www.sonobondultrasonics.com/welders-bonders/nonwovens-textiles/ringmaster.

For lower-production assembly, Sonobond's Filter Collar Bonder™ creates an equally reliable 360-degree weld between a bag and plastic ring in as little as 45 seconds, producing between 50 and 80 bags per hour.

ULTRASONIC PLUNGEBONDER

For assembling large, multi-layer and difficult-to-bond materials in just one step, Sonobond offers the SureWeld™ 20 Ultrasonic PlungeBonder™, which is ideal for sealing box-style filters and filter bag ends. In addition to producing cube filters, it's used in the assembly of automotive air filters and HEPA-rated bag-less vacuum cleaner filters.

FREE BONDING VIABILITY TEST

To ensure that manufacturers use the machine most suitable for their filter media and manufacturing requirements, Sonobond offers a free, no-obligation Ultrasonic Bonding Viability Test. The filtration assembler provides the filter materials and Sonobond creates sample bonds. If the manufacturer decides to install a machine, Sonobond makes certain that work proceeds smoothly and swiftly, providing ongoing technical support and customer service. FN

Visit Sonobond at Filtration 2014

See Sonobond's equipment and samples of the variety of filters it can assemble at Filtration 2014, Baltimore Convention Center, Baltimore, Md., November 18-20 (Booth # 603). For more immediate information and service, or for instructions regarding submitting materials for a free Ultrasonic Bonding Viability Test, visit Sonobond's website, www.SonobondUltrasonics.com, phone 800-323-1269 or 610-696-4710, or contact Vice President Melissa Alleman at MAlleman@SonobondUltrasonics.com

Tiny Particles and the Bigger Picture

Topics covered at EDANA's Filtrex 2014 conference in Berlin, ranged from sector specific and immediate issues to the broader future of transportation and manufacturing

By Adrian Wilson, European Correspondent

Discussing fuel filtration at Filtrex were (left to right): Philippe Wijns, Hollingsworth & Vose; Harald Banzhaf, Mann+Hummel; Andrew Shepard, Hollingsworth & Vose; Mark Wolfinger, Lubrizol; and Tobias Asam, SGS Germany.

Single-stage nonwoven filter media are no longer sufficient for meeting water separation efficiency requirements in modern fuel tanks and diesel fuel systems. This was one of the key messages to be taken away from the EDANA Filtrex 2014 conference held in Berlin, Germany, from October 1-2.

Another couple of messages were rather bigger in terms of their implications – that the continued growth of the global automotive industry can no longer be taken for granted, and that digital industrialization is poised to change everything anyway.

RETHINKING DESIGN

During a panel discussion on fuel filtration, Andrew Shepard, director of global market management at Hollingsworth & Vose Engine and Filtration said that new regulations for diesel and other fuels are currently impacting all along the supply chain in respect of:

- Emissions requirements
- Fuel quality
- Biofuel impact
- Sustainability
- Service intervals
- Compliance testing

All of this, he said, is resulting in the need to rethink filter design, because at the moment, particulate removal is the key goal.

In diesel engines, however – and those with bio content, which are even more vulnerable – water removal needs to be the first priority.

Water enters the fuel tank and diesel fuel in a number of ways. Sub-standard fuel with a high water content can be a

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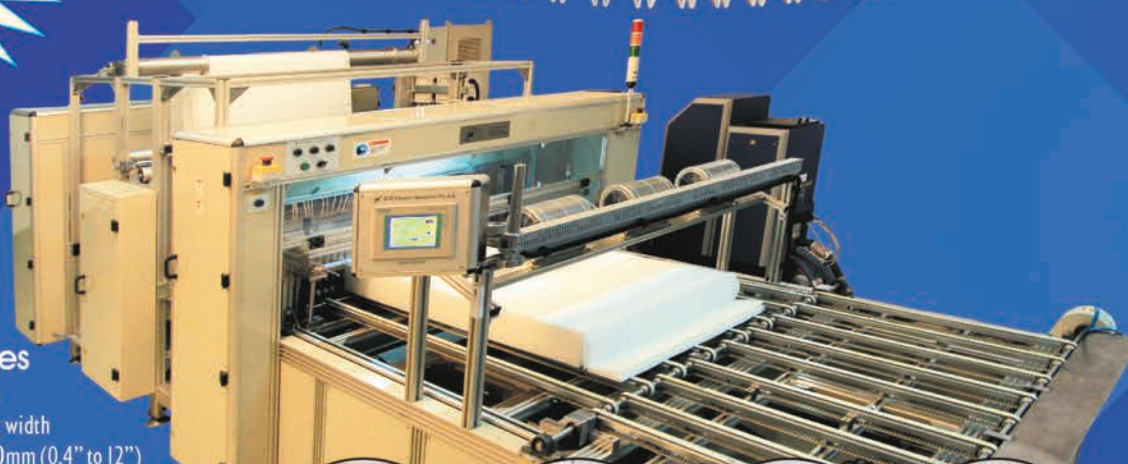

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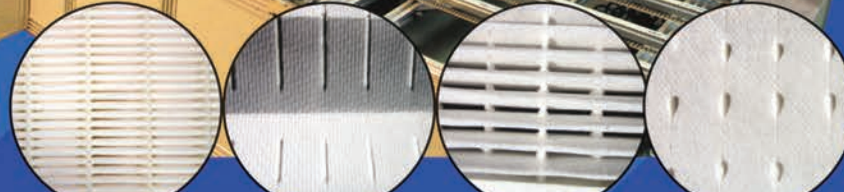

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Mann+Hummel's Multigrade introduces a three-stage filtration concept to cope with new fuel demands.

possible cause, as can misfuelling, the ingress of water via the fuel tank ventilation or condensation.

The consequences include corrosion and cavitation on injectors, valves and the injection pump – which can ultimately lead to a system failure. In addition, free water can cause microbiological growth and corrosion processes, which frequently lead to premature blockage of the fuel filter or pitting corrosion of the filter housing.

Today, commercial vehicle engines are developed for global use. Modern fuel filter systems must therefore meet a variety of demands in terms of fuel quality, contamination, water content and use with regard to their filtration and separation requirements.

SINGLE-STAGE CONCEPTS

In the past, single-stage concepts were sufficient to meet the requirements for water separation efficiency. For this purpose, the filter element was equipped with a water barrier layer on the flow side. This concept, however, is no longer adequate for pressure side filter operation or for the use of modern low-sulphur fuels, which contain biofuels and have a high additive content, in order to effectively protect the injection system from damage.

If water from the fuel tank enters into the fuel circuit, it is broken up into small droplets in the low-pressure fuel pump. After several fuel cycles, extremely small droplets may form. A stable fuel/water emulsion then forms, which does not separate, even over several days.

Separating small droplets presents a challenge for fuel filter systems – filter elements that are based on a water repellent effect on the flow side of the filter cannot ensure water separation in the long term. The small droplets are not separated at the surface but as a result of their size, are forced through the pores of the filter medium. The hydrophobic properties are impaired to such an extent, particularly by additive components in biofuel and separated impurities, that the water separation capability is completely lost over the service life of the filter.

MULTIGRADE

"The more contaminated the fuel, the greater the filtration requirement," said Harald Banzhaf, director of R&D in liquid filter elements at Mann+Hummel, headquartered in Ludwigsburg, Germany. "The injection technology in common rail systems already operates at 2,500 bar pressure and now Bosch, for one, is talking about going up to 3,000 bar, which will require even cleaner fuels."

In order to ensure reliable water separation over the service life of the filter element, Mann+Hummel has developed a three-stage filtration concept, which is used in its latest Multigrade filtration modules.

With this concept, the fuel flows from the outside to the inside of the filter element. In the first stage, solid particles are filtered out and it's crucial that the coalescer and the hydrophobic fabric are not contaminated by particles. The coalescer then retains the water droplets and combines them to form much larger drops. In the third stage, the hydrophobic screen fabric prevents the drops from following the fuel into the injection system. The separated water itself is collected in the filtration module, detected there and emptied out either manually or automatically. Thanks to the high water separation efficiencies that can be achieved, the injection systems and commercial vehicle engines are reliably protected.

MOBILITY

But while there may be currently more than fifty filters in an average passenger car or truck – contributing to functions ranging from the performance of the engine, oil and fuel consumption through to the quality of the air in the cabin – Philip G. Gott, of leading U.S. analyst IHS Automotive, based in Lexington, Mass., said that the world is in the early stages of a massive shift in consumer preferences for personal mobility.

Congestion, he said, now costs cities billions each year. It impedes the efficient movement of goods and as a result manufacturing within them stalls, with employers moving out.

"At the same time, it's beneficial to keep people clustered in cities, so mass transportation infrastructure and alternatives to the car are essential for progress. Car ownership peaks as a function of population density and at ten thousand people per square kilometer it starts to go down."

The growth of the new light vehicle market, he predicted, may soon level out at an annual 100 million units, which will mean 30 million less of them will be produced each year than has previously been forecasted going forward. And by 2035, this will mean there will be 260 million fewer light vehicles on the roads than there are today, as older cars reach the end of life and are not replaced.

Asian cities, Gott suggested, will not grow to the motorization rates of the West, and indeed, Beijing has already imposed a cap on new vehicle registrations to keep the overall number of vehicles down to 150 per thousand people.

"Such measures will mean slower growth for replacement filters in the next 20 years, but at the same time, systems that improve air quality in mass transit and other shared vehicles will provide new opportunities," he concluded.

NEW MANUFACTURING

Another keynote speaker at Filtrex 2014, Robert Glaze, of the Brenva Institute, based in Colorado Springs, Colo., believes even greater changes are in the pipeline.

Five years ago, said Glaze, overall technology R&D could be divided into one third biotech, one third new energy and one third communications and computation.

"Today, it's one third biotech, one third computational science and one third new manufacturing, and digital industrialization is the next revolution," he said. "3D and 4D printing is leading to a rapid materials evolution and machines are becoming ever smarter. There will be end-to-end automation as machines replace humans at an ever faster rate."

Some of the things that are coming next, he suggested, include:

- Brain computer interface and affective technologies
- Multi functional additive manufacturing and molecular recombination
- Predictive and anomaly analytics
- Increasingly rapid prototyping for speed to market
- 3D bio printing, bio chips and neuro technologies

4D PRINTING

"MIT has already developed context-aware materials via 4D printing, and 3D printing is already more sophisticated than you think," said Glaze. "Machines will soon become co-workers and colleagues. The major chemical companies, meanwhile, are very worried about molecular recombination technology because it threatens to put them out of business. This all implies changes in corporations and manufacturing companies as much as it does manufacturing methods.

"We're going to see the disintermediation of labor as flow analytics replaces individual metrics and organizations evolve into non-human-based ecosystems, along with distributed intelligence in networks, systems and, ultimately, humans. This will be a major challenge, and already, Apple has plans in place to eliminate its entire existing supply and retail chains – involving a million people around the world – in the next five years. Instead of holding inventory, it now plans to install its own huge 3D printing machines strategically around the world."

Polymer Removal from Metal Filters

By Sue L. Reynolds, Carolina Filters, Inc.

Metal Filter Bundle before and after polymer removal

Because metallurgy and construction of equipment and filters used in chemical and polymer processes are specified so that the parts can withstand the pressures, temperatures, and/or corrosiveness of those processes, the parts can be expensive. The high cost of such equipment necessitates its reuse, which creates the need for polymer removal. Methods selected to remove the polymer depend not only on the polymer but also on the part – its configuration and metallurgy. The chemical reactivity/stability of the metal in relation to cleaning chemicals must be considered. If high temperature methods are used, temperature limitations and atmospheric environments become important. Because of the expense and fragileness of parts and filter media, special care must be used in choosing the method of polymer removal.

The term "polymer" refers to a substance formed by linking one or more species of atoms or groupings of atoms together in long sequential patterns usually by covalent bonds. The method and type of linking converts simple molecule(s) into poly-molecular structures that provide various desirable properties. While formulating and producing polymers can be challenging, removing polymers from filters or parts will present a different set of issues. Understanding the chemistry and mechanism of a polymerization reaction can be valuable in determining how to safely remove polymer from the structure.

Since most polymers used in the manufacturing of plastics are not soluble in water or other non-regulated solvents, depolymerization may be required. Depolymerization "unzips" the polymer chain to form smaller units, such as monomer, dimer, etc., which may dissolve in or react with cleaning agents. In other cases, there may not be appropriate solvents or solutions that can be used to remove the polymer or its smaller units. In those cases, high temperature or alternative options may be required.

For example, consider the following general polymerization reactions in Equation 1:

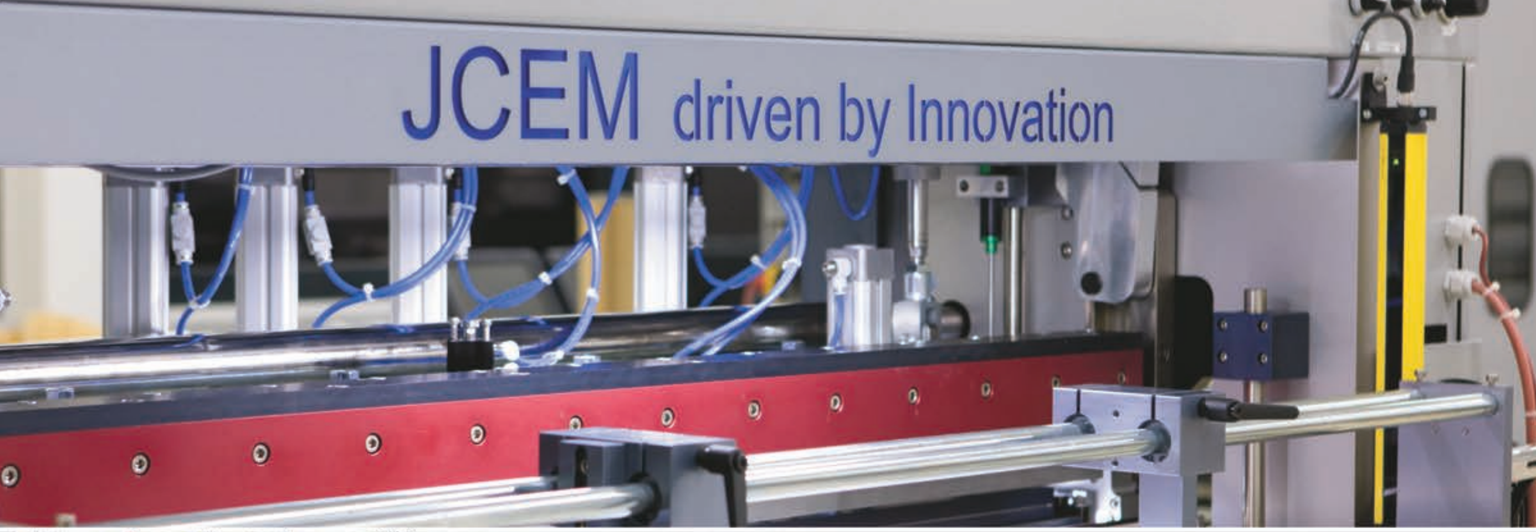
Equation 1: Typical Condensation Reaction:

$$HOOC\text{-}R^1\text{-}COOH + HO\text{-}R^2\text{-}OH \rightarrow [\sim O\text{-}R^1\text{-}OOC\text{-}R^2\text{-}CO\sim]_n + (n+1)\,H_2O$$

Equation 2: Typical Addition Reaction:

$$n\,CH_2 = CH_2 \rightarrow [\sim CHR^1 - CHR^2\sim]_n$$

where "R" represents an organic or an organic/ inorganic group



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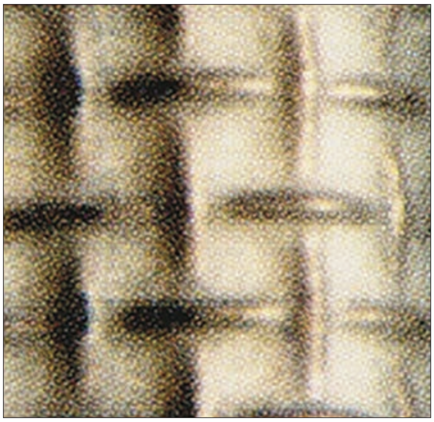
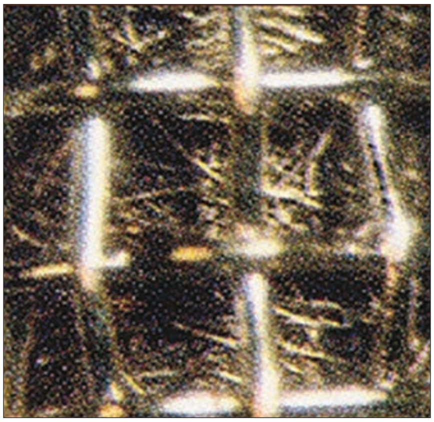



Filter Media before and after polymer removal.

In polymer chains such as Equation 1, the chain will generally undergo hydrolysis reactions, whereby the polymer chain may be attacked by hydroxylated compounds at the acyl or carbonyl carbon positions. Glycols are among organic solvents commonly used for such polymers. In some cases, depending on the strength of the bonds around the carbonyl group(s), steam or aqueous solutions of acids and bases may be used. DEECOM®, an alternative technology to chemical methods, uses mechanical decompressive energy along with hydrolysis to remove the polymer. The degree of hydrolysis during the DEECOM process is dependent on operating parameters. Examples are polyester, nylon-6, and polycarbonate.

For polymers represented by Equation 2, solvents regulated by the EPA, such as aromatic or halogenated solvents, may be required. To avoid storing and using these solvents, burnout processes are typically used. Vacuum Thermal Cleaning Systems, such as VacuClean®, and Convection Ovens, such as Steelman & Pollution Control Products, provide differing methods of oxygen control as needed for the safety of the type of part or filter being processed. Examples are polyethylene, polystyrene, and polytetrafluoroenthane.

The method and level of difficulty in removing polymers from metal filter media can be affected by:

- Types and locations of functional groups
- Types and locations of alkyl groups
- Polymer chain configuration (i.e., linear, branching, cross-linking, etc).

Because many polymers are composed of various polymer types, combinations of removal methods may be necessary. A major point to consider is that the method of polymer removal must not be damaging to the filter or part.

Since the method of polymer removal is dependent on characteristics of both the filter media metallurgy/construction and the polymer, before developing a method of polymer removal, several things must be considered.

1. Characteristics of the metal and type of filter or part

Composition: The material of construction of the part, i.e., type of stainless steel, exotic alloy, or carbon steel, will determine the chemicals that can be used to clean the part.

Temperature Limitations: Some metals have temperature limitations, which if exceeded can cause irreversible effects on the metal, such as sensitization, changes in hardness, and maybe even melting.

2. Characteristics of the polymer

Physical Properties: Solubility, melting parameters, heat flow characteristics, response to ultrasonic, brushing,

Table: Comparisons for Depolymerization Methods

	Thermal Oxidation can occur	Sensitization can occur	Possible chemical attack	Temps > 430°C are possible	Removes carbon, & degraded polymer	Removes inorganic particulate	Post-Cleaning Needs
Convection Ovens	Yes	Yes	No	Yes	Yes	No	Medium
Vacuum Ovens w/oxidation	Not Likely	Yes	No	Yes	Yes	No	Low/ Medium
Salt Baths	Yes	Yes	Yes	Yes	Yes	Some	High
Solvents	No	No	No	No	No	Some	High
DEECOM®	No	No	No	No	Yes	Yes	Low/ Medium

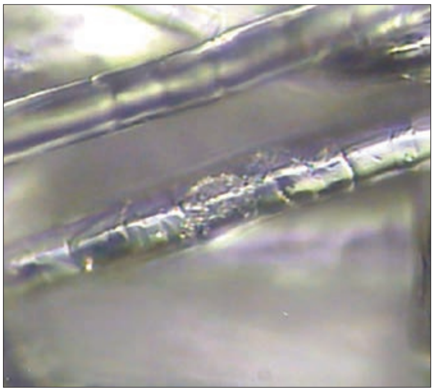
and other physical forms of removal

Chemical Properties: Chemical reactivity, response to heat under atmospheric vs vacuum conditions

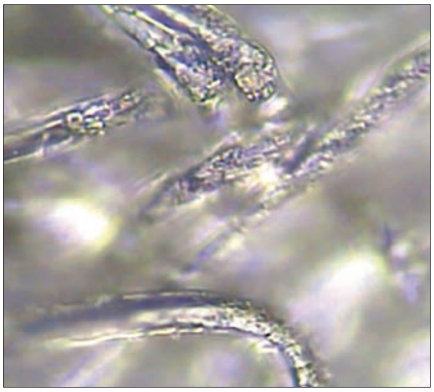
It is important to note that in terms of depolymerization processes, the specific filter or part and polymer must be individually considered. See Table: *Comparisons for Depolymerization Methods*. While the table provides comparisons of various depolymerization processes, the results are qualitative, not quantitative, and are based on general and not specific process examples.

In summary, to recycle or reuse expensive metal filters, the first step is to remove the polymer or major contaminant. How this is done can affect the life and overall performance of the filter. The major factors in selecting the depolymerization process are the filters and the polymer. To remove the polymer safely and effectively, it is necessary to:

- Understand the chemistry of the polymer being removed and the construction and constraints of the filter media
- Develop a process that removes the polymer without damaging the filter media
- Control the process conditions during polymer removal



Good media



Media damage from burning

FN

About the author

Sue L. Reynolds has been with Carolina Filters since 1990. During that time, she has worked in all aspects of the cleaning operation with major duties involving process development, procedures, and working with customers in Technical Sales.

She has a BA in Chemistry from Winthrop University and a Masters in Mathematics from the University of South Carolina. In the past, she worked in the education field teaching chemistry, physics, and various levels of mathematics in private & public schools, at the University of South Carolina, and at the Carolina Technical College.

She is affiliated with numerous scientific and filtration organizations and has published several papers that cover various aspects of cleaning.

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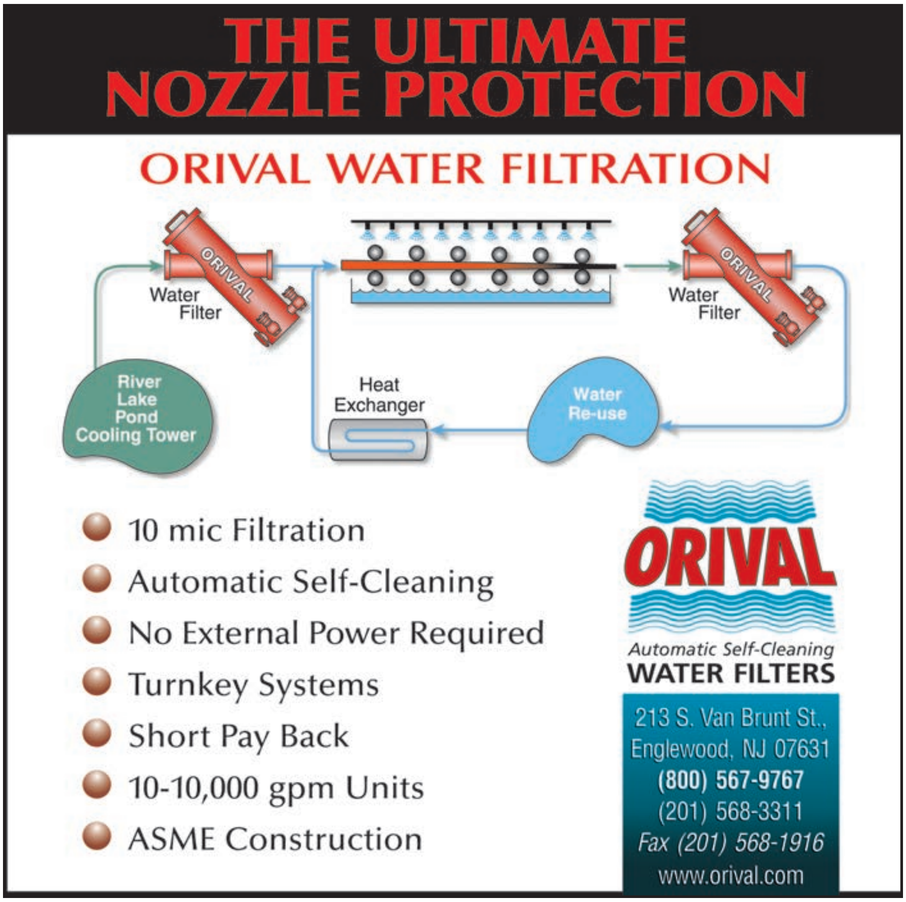
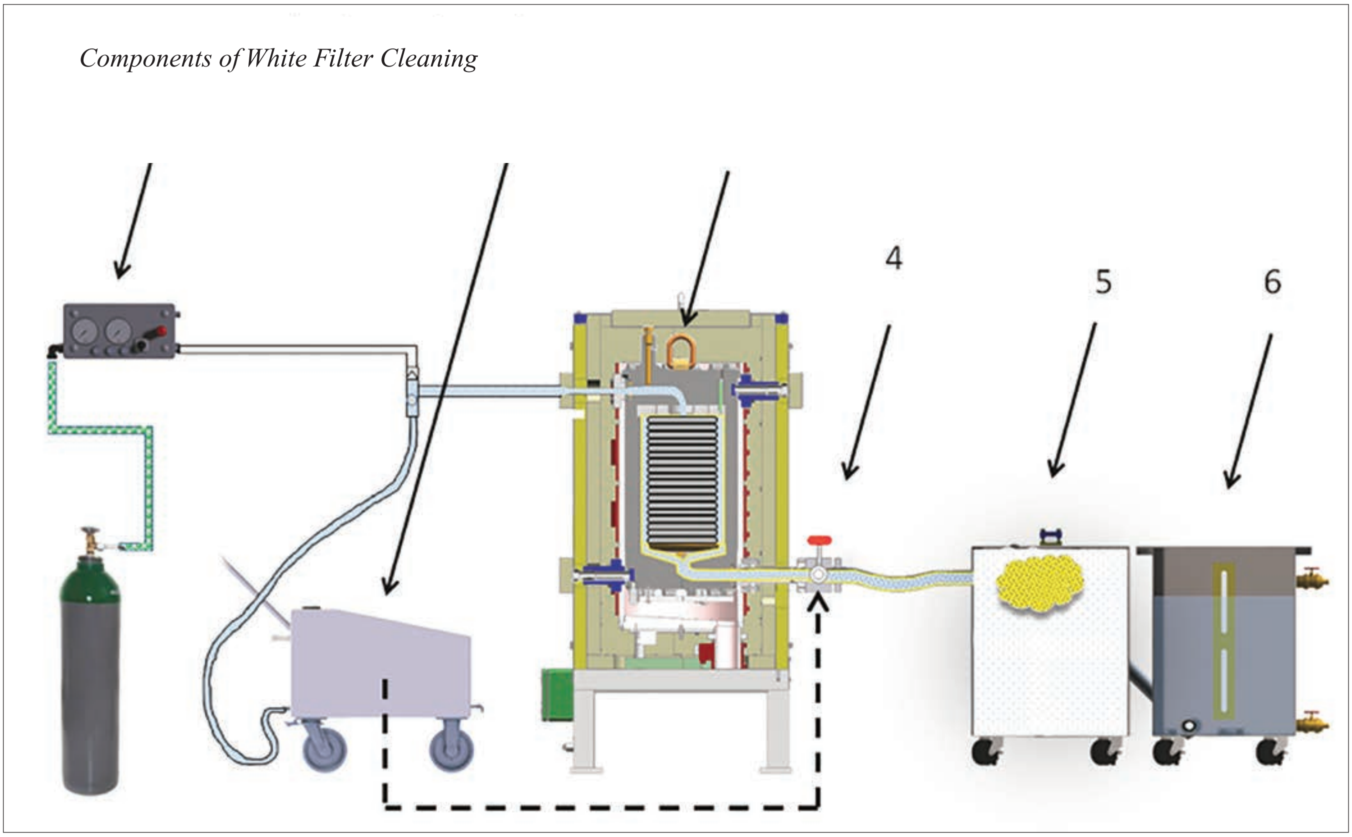


New Polymer Filter Cleaning Equipment

Dipl.-Ing. Jörg Alexander, Engineering Extrusion Technology



Schematic of the main components of a WFC set up.

BB Engineering, a joint venture of Oerlikon Manmade Fibers (formerly Barmag) and Brückner Group has developed new filter cleaning equipment for polymer filters. It is marketed under the trade name WFC – White Filter Cleaning.

It is meant to clean filter inserts from production lines processing PETP, PA6 or PC. The filter elements can be candles or disks. The cleaning effect is based on a combination of hydrolysis and gas flow dynamics.

The filter inserts are flown through by superheated steam in reverse direction (in relation to regular polymer flow). The superheated steam is kept under overpressure for some time (hydrolysis) and then suddenly released via a quick opening decompression valve (gas flow dynamics).

This cycle is repeated for several hours, each cycle carrying some polymer out of the filter.

The decompression process is derived from the proven deecom® Process by B&M Longworth Ltd.

The cleaning method is as effective as any other cleaning method, such as solvent cleaning. After having removed the polymer via WFC, the filter inserts can be taken apart easily and the filter elements are given into subsequent cleaning steps.

The main advantages of WFC are:

- No solvents required. This saves money and avoids environmental and fire hazard problems
- Filter cleaning can start just after having taken the filter out of service without cooling and reheating period. This avoids damages to the filter elements due to shrinking effect under polymer solidifying and saves

energy costs.

The main components of a WFC set up are:

1) Preheating and Draining – station for the filter insert (often at hand anyway)
2) Nitrogen supply including control box
3) Steam supply with safety devices and SPS for supervising the cleaning procedure
4) Decompression valve (motorized)
5) Residue collecting box
6) Condenser box for transferring the superheated steam into liquid water

The cleaning equipment (photo to the right) is also suitable for filters of other brands and for cleaning other machine parts such as spinnerets, breaker plates, valves and melt pipes.

BBE's White Filter Cleaning equipment

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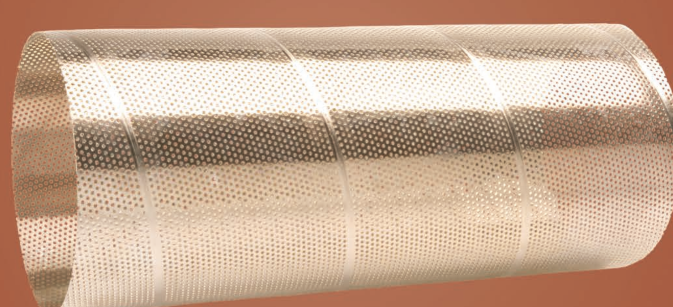

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Application Specific Adsorption Rating Method for Nanoscale Polymer Membranes

By Tony Shucosky, VP Marketing; Toru Umeda, SLS Technical Mgr.; and Shuichi Tsuzuki, SLS Center of Excellence Leader, Pall Corporation

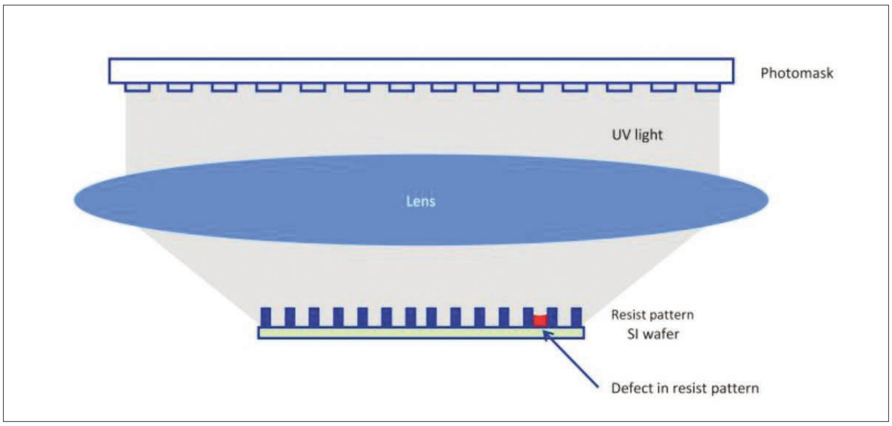

Figure 1. Microbridge is a device killing defect that is a small connection between two adjacent lines in photoresist.

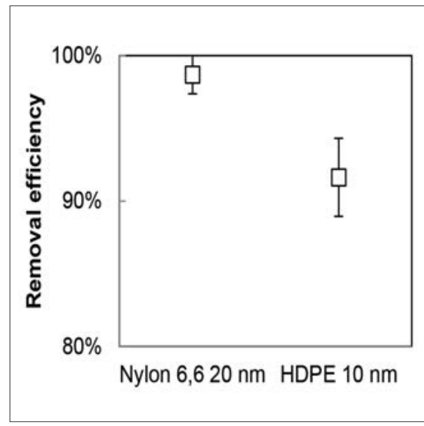

Figure 2. Microbridge defect removal efficiency by different polymer membranes.

In the challenging world of filtration in the semiconductor manufacturing industry, the current manufacturing nodes are being designed with feature sizes such as line widths approaching 10 nm in size. The ITRS considers particles about one half this size to be of a critical particle size capable of causing circuit defects[1]. Even more critical is the lithography application in which a circuit pattern is transferred to the semiconductor substrate by using a thin layer of photoresist. These thin layers ultimately define how closely the features are spaced and how the circuits function. A majority of contamination on a wafer can occur during patterning. A single critical particle sized defect on a pattern can cause a circuit failure and worthless device. Complicating the issue is the fact that defects in this nanometer size range can also be the result of dissolved or partially dissolved gels as well as hard particles.

In order to develop membranes that remove these defect causing precursors, a method is needed that simulates the application conditions of fluid and contaminant. Application specific filter rating test methods have proven to be of value for many applications in many other industries. Most of the rating test standards rely on a model that describes the effectiveness of the filter in removing essentially solid particles from the fluid through one of a number of removal mechanisms. The primary removal methods in the case of liquids are direct interception (sieving) and adsorptive sequestration. Few methods exist for microporous membranes with sub 50 nm pore sizes that rely mainly on adsorptive capture mechanisms.

In the semiconductor lithography application, a common type of defect in on-wafer resist patterning is known as a microbridge defect. See Figure 1. It can be caused by hard particles, which can be removed by sieving. It can also be caused by microbridge precursors that can be preferentially removed by adsorptive interaction between the precursor and the membrane. This defect source is believed to be an aggregated gel of hydrophilic and low solubility polymer fraction that is found in the DUV photoresist.

Figure 2, shows the microbridge reduction by filtration using two different membrane polymer materials, Nylon 6,6, and HDPE (high density polyethylene). Even though the HDPE membrane is rated as a finer 10 nm filter based on hard particle sieving, the coarser 20 nm rated Nylon 6.6 membrane is more effective in removing the gel. It is believed that the gels are adsorbed onto the hydrophilic amide bonds on the Nylon 6,6 membrane. The ability of adsorptive Nylon 6,6 membrane to remove microbridge defects in the filtration of DUV resist in the lithography process has been repeatedly documented. [2,3,4]

In order to develop an application specific adsorption performance rating for use with nanometer pore size membranes, a model was developed to simulate the application conditions that could be duplicated in the labo-


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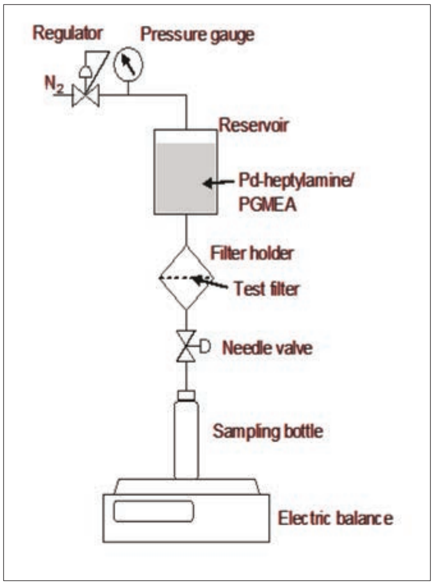

Figure 3. Steady flow filtration test stand with 0.5 ppb Pd-Heptylamine in EL grade PGMEA. Test filters were Nylon 6,6nm and HDPE 30 nm.

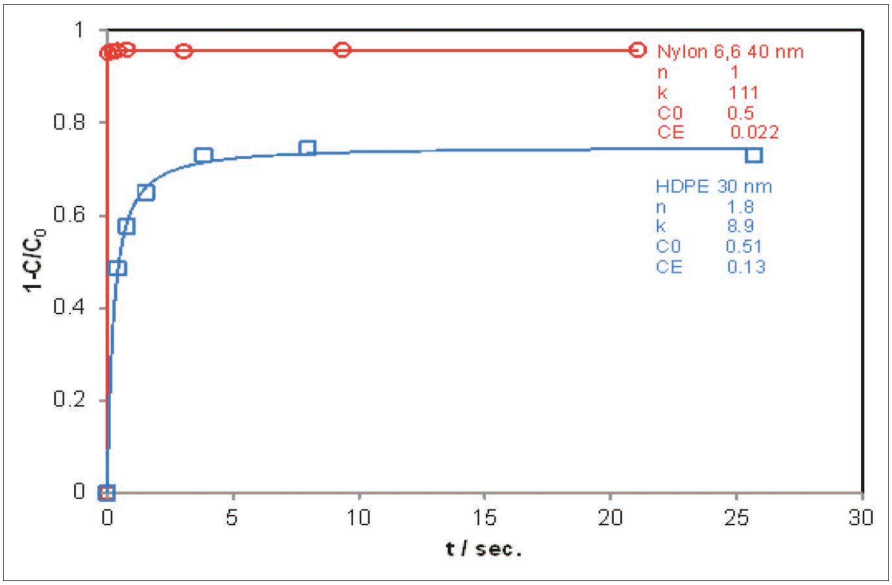

Figure 4. Surrogate particle removal efficiency (1-C/C0) by adsorption based on contact time for two different membrane polymer materials. Fit lines are based on adsorption rate equations.[7]

ratory. Specifically needed was the selection of a

1. Membrane filter
2. A commonly used application fluid
3. Surrogate particle (defect source)
4. Simulated test system

1. Two membrane filters were selected for the model development. A 40 nm rated asymmetric Nylon 6,6 membrane and a 30 nm rated HDPE membrane.[5] These filters are representative of filters currently in use in the application of interest.

2. A commonly used chemical in the photolithography process is a solvent known as PGMEA, propylene glycol mono methyl ether acetate. This was selected as the application fluid.

3. The targeted defect source is the microbridge precursors. They are gel-like particles in both the EUV and DUV lithography processes. They are primarily removed via adsorption. To develop an application specific method, a simulation particle that mimics almost exclusively the adsorptive properties alone was needed.

Metal nanoparticles of Pd-Heptylamine were selected as the simulation particle that would most closely produce the desired adsorptive properties. By using metal nanoparticles much smaller than the membrane pore size, the sieving is minimized. This was confirmed in earlier testing.[5] The adsorption characteristics were then simulated by attaching selected ligands to the particles.

The adsorption of these defect precursors on Nylon 6,6 seen in Figure 2 is believed to be a result of the polar interactions between amine groups on the ligand and the hydrophilic amide bonds on the Nylon 6,6. Testing using the apparatus shown in Figure 3, showed that the alkylamine ligand substituted nanoparticles was more readily adsorbed on Nylon 6,6 membrane than the HDPE membrane, and provide a good model that matched actual application performance.

4. The test system used a rig capable

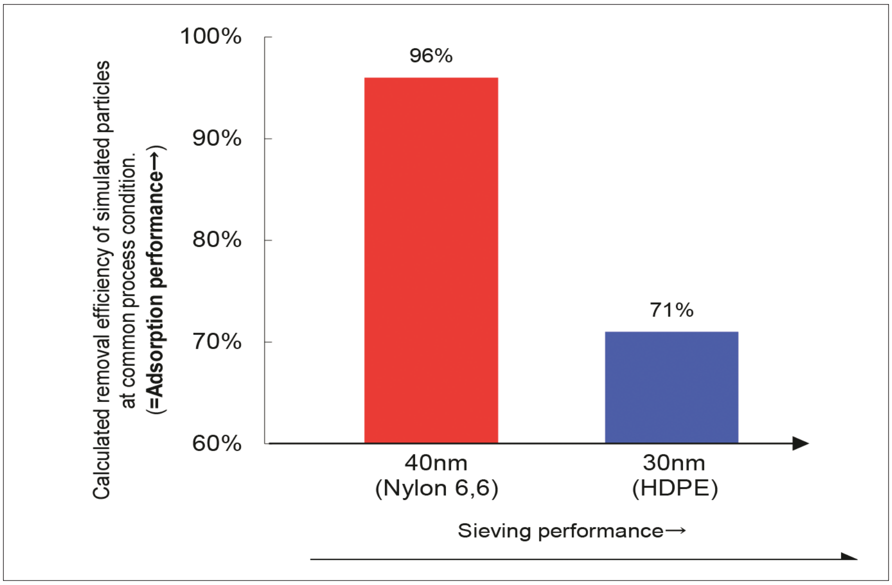

Figure 5. Adsorption performance based on surrogate particle filtration tests. The established removal rating is an indication of expected sieving performance.

of applying the same operating conditions as those found in the actual application. Regulated nitrogen gas pressure was used to push the mixture of solvent and particles through 47 mm diameter membrane disc samples at different flow rates typically found in the application. 10 gram samples of effluent were collected in a sample bottle and analyzed. Concentrations of Pd in the influent and effluent were measured by ICP-MS.

By changing the flow rate, the removal efficiency of the test particles as a function of contact time was measured. Figure 4 shows the removal efficiency of the 4 nm metal nanoparticles as a function of contact time. The Nylon 6,6 40 nm filter shows faster and greater adsorption than the 30 nm HDPE filter.

APPLICATION SPECIFIC BASED RATINGS

The adsorption parameters determined can be used to predict removal efficiency performance at a given resist dispensing flow condition. Figure 5 is an example of calculated equilibrium removal efficiency, due to adsorption, for selected membrane filters[5].

CONCLUSION

Many critical defect particles in advanced semiconductor manufacturing are in the nanometer size range, beyond the level of current particle metrology instrumentation, and are most effectively removed through adsorptive sequestration. A predictive model has been developed that will aid filter makers in the development of nanoscale removal membranes. It may also benefit users like advanced lithography developers in the selection of membranes to achieve desired results in next generation processes.

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7. *n*th order adsorption of an equilibrium process can be described as: $\frac{d(C-C_E)}{dt} = k(C-C_E)^n$ where C = adsorbent conc, *t* = contact time between adsorbate and adsorbent, n = adsorption reaction order, *k* = adsorption rate constant, C_E = adsorbent equilibrium concentration.

Applications and Limitations of Membrane Technologies

By Ben Movahed, President, WATEK Engineering Corporation

Example of Ultrafiltration Membrane Facility

As water quality regulations become more stringent, membrane options have become more attractive than conventional treatment. In addition, technological advances in membrane have decreased costs significantly making it more economically comparable to other treatment options.

The most common types of membranes are low-pressure membranes including microfiltration (MF) and ultrafiltration (UF) for water and wastewater treatment, and Membrane Bio-Reactor (MBR) for wastewater treatment. High-pressure membranes such as nanofiltration (NF) and reverse osmosis (RO), and non-pressure, electric potential driven membrane called Electro Dialysis Reversal (EDR) are used for desalting and contaminant removal.

LOW PRESSURE MEMBRANES

MF and UF membrane filtration technologies have emerged as viable options for addressing the current and future drinking water regulations related to the treatment of surface water, groundwater under the influence, and water reuse applications for microbial and turbidity removal. MF/UF membranes are effective at removing particulate matter and have 5+ log removal capabilities for Giardia and Cryptosporidium. Most MF/UF systems operate with high recoveries of 90–98%. Full-scale facilities have demonstrated the efficient performance of both MF and UF as feasible treatment alternatives to conventional granular media processes. Both systems have been shown to exceed the removal efficiencies identified in the Surface Water Treatment Rule such as Cryptosporidium oocyst, Giardia cyst and turbidity. MF and UF membranes are most commonly made from various organic polymers such as cellulose derivatives, polysulfones, polypropylene, and polyvinylidene fluoride (PVDF). Physical configurations include hollow fiber, spiral wound, cartridge and tubular.

In response to a changing economic climate, MBR is commonly viewed as an option for the retrofit, expansion and upgrade of aging infrastructure to meet new nutrient limits or increase plant capacity. MBR technology is also ideally suited for an array of municipal and industrial water reuse applications such as irrigation, aquifer replenishment, wetlands development, industrial process water, boilers and cooling systems. MBR systems provide this high effluent quality in a greatly simplified process, requiring only headworks, biological process, membrane filtration, and disinfection to meet the most stringent water quality standards. In comparison, conventional process requires additional primary treatment, secondary clarifiers, Enhanced Nutrient Removal and media filtration in order to obtain the same effluent characteristics. Additionally, there is ever increasing regulations related to pathogens, viruses and other constituents of concern, which are not typically reduced to desirable levels by conventional treatment processes.

HIGH PRESSURE MEMBRANES

RO membrane technology has been successfully used since the 1970s for brackish and seawater desalination. A lower pressure RO technology, NF, also known as "membrane softening," has also been widely used for treatment of hard, high color and high organic content feed water. NF also has a high rejection capability for divalent ions such as iron, calcium, magnesium, etc. Reverse osmosis systems are also utilized for removal of inorganic contaminants such as radionuclides, nitrates, arsenic and other contaminants such as pesticides and viruses.

RO is a physical separation process in which properly pretreated source water is delivered at moderate pressures against a semi-permeable membrane. The membrane rejects most solute ions and molecules, while allowing water of very low mineral content to pass through. This process also works as an absolute barrier for cysts and viruses. The process produces a concentrated reject stream in addition to the clean permeate product. By-product water or the "concentrate" may range from 10% to 60% of the raw water pumped to the reverse osmosis

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Example of Brackish Water RO Facility

unit. For most brackish waters and contaminant removal applications, the concentrate is in the 10-25% range, while for seawater, it could be as high as 50%.

A non-pressure, electric potential driven membrane, EDR, has also been widely used for removal of dissolved substances and contaminants. In EDR, a variation of electro-dialysis, the electrical potential applied by the electrodes is periodically reversed. This causes the direction of migration of the ions to reverse, and switches the functions of the flow channels so that the dilute channel becomes the concentrate channel and vice versa to flush the membrane spacers. Thus, EDR tends to reduce the buildup of scale and foulants on membrane surfaces.

SELECTING A MEMBRANE

Choosing the right membrane process is vital when it comes to long-term performance and success of a membrane plant. Some of these membranes are not chlorine or oxidant tolerant, and depending on the raw water chemistry, there is a potential for scaling and fouling. This significantly reduces the life of the membrane and increases production and membrane replacement costs. These are the biggest disadvantages of membranes and should be carefully considered for every project.

Pilot plant testing offers the best method for evaluating the feasibility of a membrane application for a specific water supply and comparing the applicability of several membranes. For plants utilizing groundwater or groundwater under the direct influence of surface waters (GUDI), the design parameters are typically well known and there is not much concern with fouling and cleaning. However, surface waters tend to vary in temperature, chemical composition and organic/metal/solids loading seasonally and during storm events, making most sources unique. Through pilot testing, the source water can be assessed and a focused and tailored design can be created, resulting in a more reliable and efficient facility.

Although most membrane manufacturers are capable of recommending an applicable membrane configuration, the engineer provides a custom design and coordinates of the entire treatment system, which also includes the membrane modules/skids/cells, feed pumps, chemical feed systems, pretreatment systems, energy recovery devices, cleaning systems, and instrumentation and control systems. A knowledgeable design engineer serves as a single source of contact, responsible for coordinating all these systems and various individual components required in a treatment plant. This coordination is crucial to the compatibility of all related systems and the smooth implementation of the project.

ABOUT WATEK

WATEK Engineering Corporation is a full-service water and wastewater engineering firm with capabilities ranging from feasibility studies to complete engineering and design as well as testing and training for advanced water and wastewater treatment facilities. The company was formed in 1995 and in the last 15 years, the primary focus of the firm has turned to desalination, contaminant removal and membrane filtration technologies.

WATEK engineers have been involved in and are focused on the study and design of various sizes (up to 100 MGD) and types of membrane technologies for surface water, softening, and brackish water/seawater desalination and contaminate removal.

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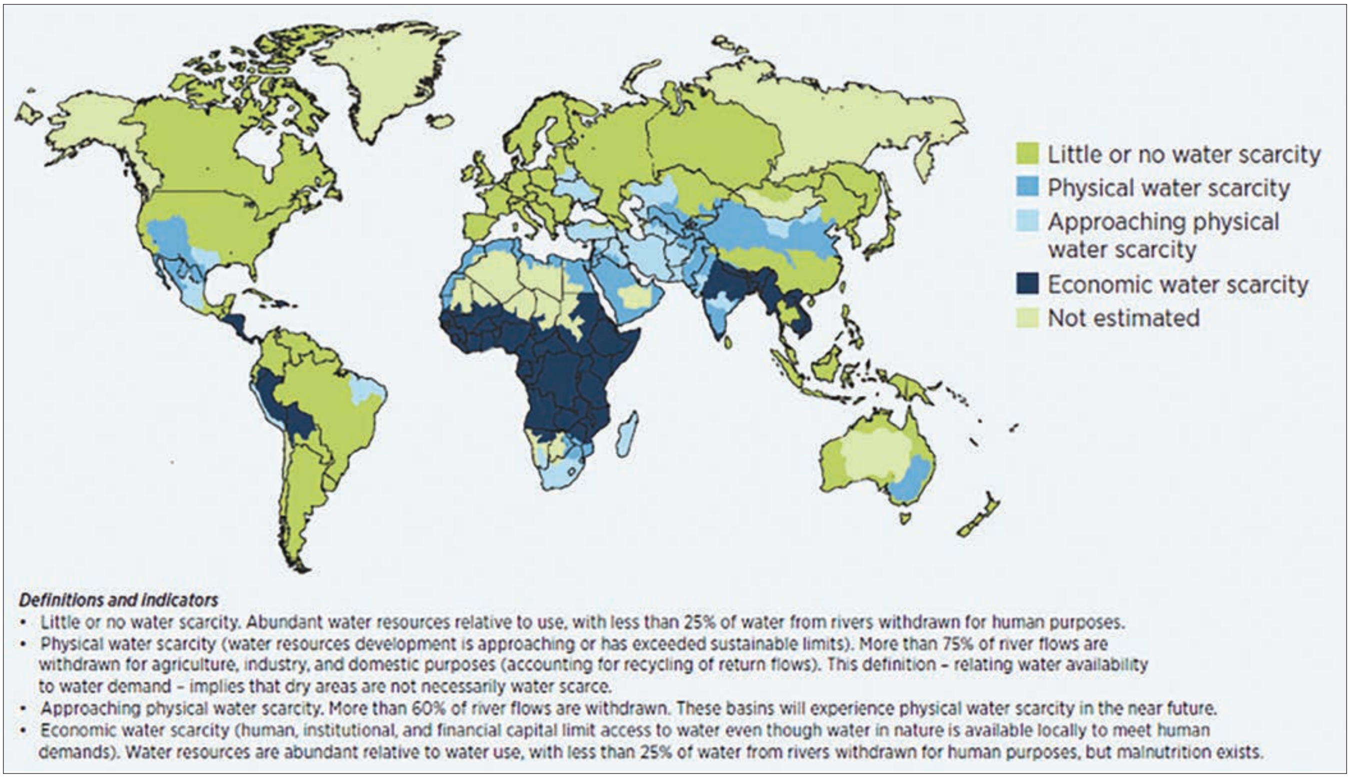
Better Adhesives for Better Liquid Filters

By Kevin Schneider, Business Manager - Membrane Separation, H.B. Fuller



Global physical and economic water scarcity. Source: United Nations World Water Development Report 4

Water is one of the most sought-after resources on the planet. Water demand—for drinking, food, pharmaceutical and medical applications, and industrial processes—is being driven by many factors including a growing middle class and increased industrialization. As the system comes under increasing stress we are increasingly turning to alternate water resources that require purification. Filtration, specifically membrane separation, from small home systems to huge municipal or industrial systems, is the most widely used method of removing unwanted impurities from water or aqueous mixtures. The materials being removed range from the salt in seawater to a variety of chemicals and solids to spores, bacteria, and viruses. In some cases, cheese making for example, water is the material that must be removed to concentrate the desired solids.

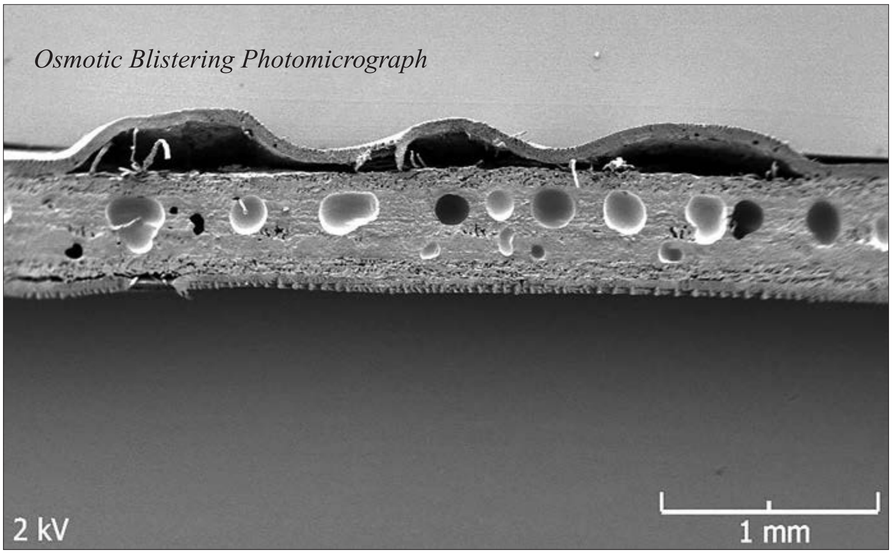
The variety of filters and membranes used to perform these separations is large and growing, and their assembly typically

Water Facts: Did you know?

- By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could live under water stress conditions. United Nations Environment Programme (UNEP) Food and Agriculture Organization
- How the world uses freshwater: about 70 percent for irrigation; about 20 percent for industry; about 10 percent for domestic use. World Water Assessment Programme
- The UN suggests that each person needs 20-50 liters of water a day to ensure their basic needs for drinking, cooking and cleaning. World Water Assessment Programme (WWAP)
- It takes an average of 3000 liters of water to produce one person's daily food. Food and Agriculture Organization
- At the end of 2012, approximately 16,000 desalination plants were in existence, producing approximately 72 million cubic meters per day of desalinated water. BCC Research

entails some sort of adhesive. While the membrane does the actual work of separation, the performance of the filter depends to a large extent on the effectiveness of the adhesive, and the demands on that adhesive can be substantial. Obviously the adhesive has to adhere effectively to the components it joins, but it must maintain that adhesion when wet and under pressure. It must withstand contacts with chemicals in the material being filtered and, in some cases, extremes of temperature. It may have to stand up to repeated cleanings without losing effectiveness. And depending on the application it may have to be food and/or drug safe and earn NSF or FDA certification. In some applications, filters can be changed regularly; in others they must last for years. The ability to meet all of these demands depends in large part on the adhesive.

When adhesive performance is less than optimal, the filter may not fail outright. It may continue to operate but do so at reduced effectiveness, allowing some of the concentrate that is being removed to bypass the filter and contaminate the permeate. A filter with less-than-ideal adhesive may have to operate at reduced pressure and throughput to avoid partial or complete failure. It may require more maintenance, adding to operational cost and increasing downtime, or it may have a shorter useful life. In other words, the filter as a system is only as strong as its weakest link, and without careful consideration the adhesive could be that weak link.



WHAT COULD POSSIBLY GO WRONG?

Adhesives that simply do not work can be quickly identified and replaced. It is far less easy to address the problem of adhesives that appear to work or that more-or-less work. These may fail slowly or fail after they have gone to market, when the cost to users and harm

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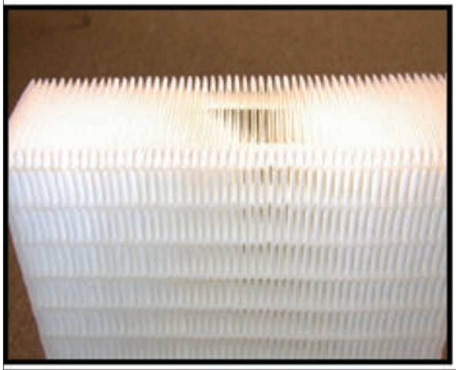
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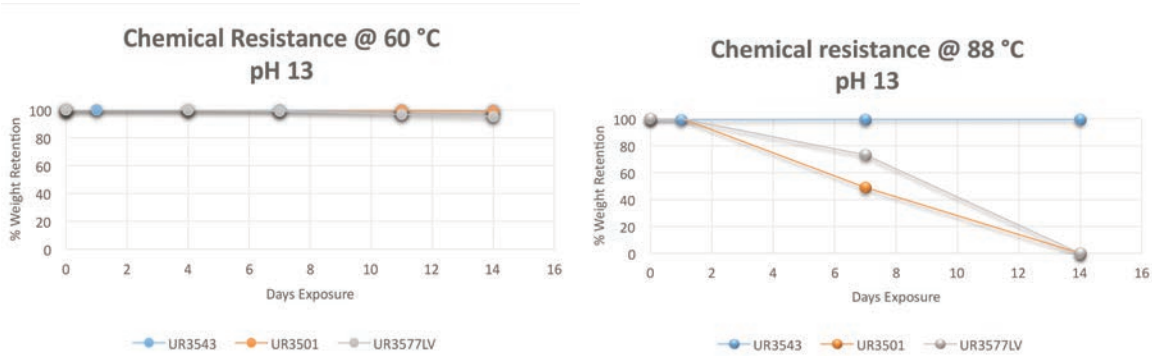
Adhesives and chemical resistance: Not all glues are alike:



One of the keys to element life span is selecting the adhesive with the right balance of performance. The charts above illustrate chemical resistance at different temperature. This data tends to show that while the three membrane bonding adhieves demonstrate similar performance at 60 °C, they have significantly different performance at 88 °C.

to producers is more serious. Some of these in-the-field failures include:

- Osmotic blistering (see side bar)
- Veining or channeling in which paths form in the adhesive through which concentrate can travel to contaminate the permeate
- Deterioration of the adhesive due to chemical corrosion or heat damage

Then there is the matter of process. Even the best adhesive is only as effective as its application. The right process and appropriate equipment help ensure the ideal quantity, placement, mix, temperature, and timing of adhesive application to maximize adhesion, minimize cost, increase yield, and prevent failure in the field.

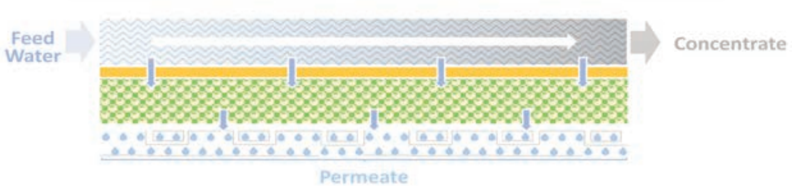
COST FACTORS

In most filter applications, the cost of the adhesive itself is small compared to other aspects of production and performance. Choosing the right adhesive and process can significantly reduce production cost for the manufacturer and cost of operation for the user. It can reduce the amount of adhesive required, eliminate material waste, reduce production downtime, increase yield, and improve all aspects of product performance. In a market with a large and growing variety of adhesives, the challenge is determining what materials and processes would best serve an application.

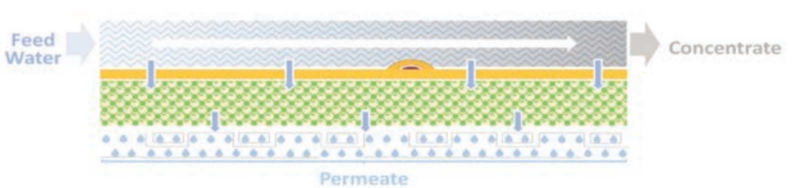
Osmotic blistering in the glue line of a spirally wound element can be problematic in operations that are subject to frequent and harsh cleaning. In food processing applications elements are often cleaned daily, using caustic or acid cleaning solutions at elevated temperature. The formation of osmotic blisters in a spirally wound element can promote the growth of bacteria. Detecting bacteria in the product will shorten the filter element's life.

Hypothesis on Osmotic Blistering:

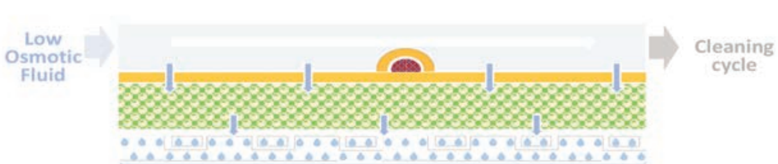
- Feed liquid is pumped through a spiral wound element in a cross flow configuration. The membrane separates the feed of high osmotic fluid into concentrate and permeate.



- Feed liquid collects in voids within the membrane or the membrane/adhesive layer



- During the cleaning cycle, the element is flushed with a low osmotic cleaning fluid. The cleaning fluid will flow, due to osmotic pressure, to the void and a blister will form



MAKING CHOICES

One of the best resources for this kind of information is adhesive manufacturers.

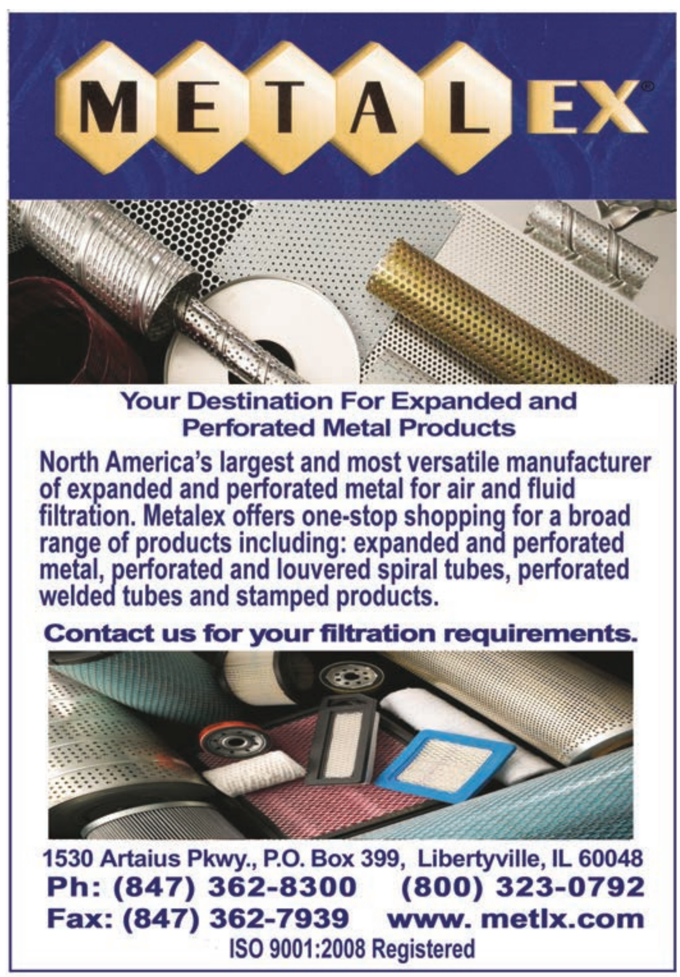
- If you choose the information provided carefully, the evaluation and decision process can be relatively quick and easy.
- For obvious reasons, the ideal resource will be manufacturers with extensive liquid separation experience.
- Look for providers offering a range of appropriate adhesives to avoid a "sell what you've got" bias.
- To avoid one-size-fits-all solutions, expect the manufacturer to study and understand your application.
- While an off-the-shelf product may work perfectly well, consider providers who are willing to modify existing products or offer tailor-made products if your application can benefit from that degree of customization.
- Any solution should address necessary equipment installation or modification, its operation, and the associated costs.
- Specs and promises are useful, but the best indication of an effective solution is a live demo closely mirroring your application.
- Providers should be able to offer reliable local service and troubleshooting anywhere the adhesive will be used.

While the above considerations apply to virtually any implementation, they are doubly true for new products. New adhesive technology can help reduce the costs and increase the efficiency of existing products, but new products virtually demand a close look at the best available adhesive offerings.

If your product will incorporate a new membrane or a new filter configuration, consider involving adhesive producers in early phases of the development process. Knowing what adhesives are compatible with your membrane chemistry or that of the products you plan to filter could affect your material choices. Similarly, understanding adhesive capabilities could allow innovations in your filter design. In short, whether developing a new filtration product or improving an existing one, better (and better supported) adhesive means a more efficient and cost-effective product, and the earlier in your development process you consider adhesives, the better and more cost effective your results will be. FN

For more information email: Kevin.Schneider@hbfuller.com, or visit www.hbfuller.com/filtration

This is Part 1 of a 3-part series on adhesives for membrane separation. Parts 2 and 3 of this series will explore specific adhesive-related issues in more detail.



Donaldson Hits Noise Reduction Targets with LMS Acoustic Simulation

Ideal solution for design changes to meet Euro 6 emission standards and tougher OEM requirements

Business is changing at Donaldson, one of the world's largest manufacturers of filters for trucks, buses, construction equipment and industrial machinery. In addition to orders for standard and custom air filters, a growing number of requests are for designing and building complete air intake systems for long-haul trucks that will meet current Euro 6 emission standards.

This shift in research and development work from the OEM to the supplier follows the trend in other segments where responsibility for system development is delegated more and more to subcontractors. The result is a win-win situation with OEMs better able to focus on total vehicle design while capable suppliers gain new business from their system-level know-how.

MIND-BOGGLING CONSTRAINTS

As Donaldson engineers can attest, landing these major contracts is no simple matter. Whereas filter orders are based mostly on specified size and materials, the air intake system must be developed around broad system requirements, such as filtered air quality and temperature, air handling volume capacity and cab noise. Teams must design and piece together a whole assembly of parts including intake nozzle, air-handling ducts, support brackets, filter housings and rubber bellows.

Complicating the task are mind-

Air intakes mounted at the front of trucks have complex geometries to fit into available space around the engine, pollution control units and other equipment.

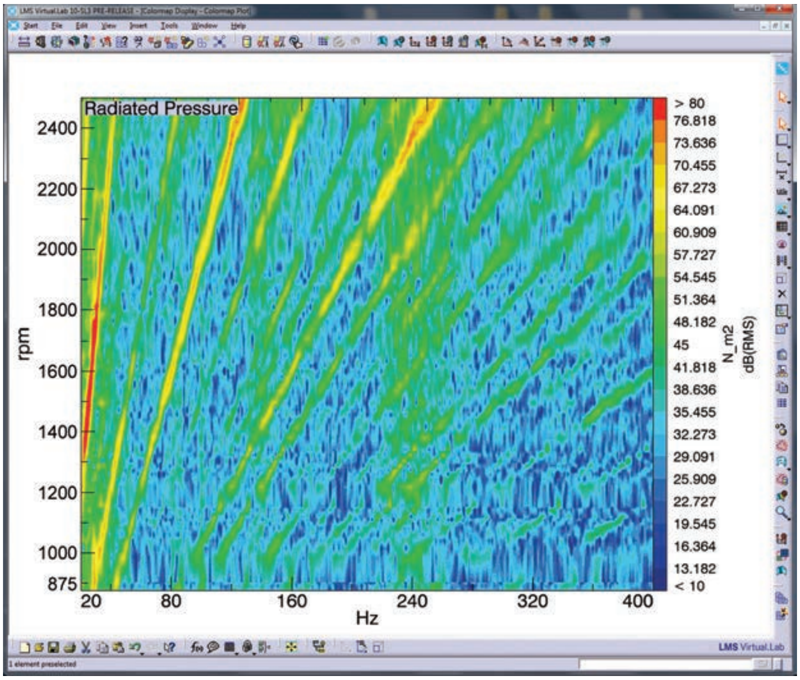
Cab acoustics impacts driver fatigue, safety and productivity, so truck manufacturers put noise reduction high on their list of design requirements.

boggling packaging constraints in which the ducts must snake their way around parts mandated by Euro 6 including the Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) units that hog up available space. Teams must also determine the best position for the intake nozzle – at the top or rear of the cab, or near the nose of the truck – a critical factor impacting air quality and temperature, and therefore engine efficiency.

TRUCK CABS AS QUIET AS CARS

One of the most challenging aspects is to ensure that the air intake system will not contribute excessively to either the cab noise or pass-by noise levels of the vehicle, in practice this means keeping its contribution 10dB lower than the vehicle target sound pressure level. For example, if a vehicle has a target of 70dB for the total cab sound pressure level at cruising speed (100km/h), the target contribution sound pressure level of the air intake system should be below 60dB.

"Cab acoustics impacts driver fatigue, safety and productivity – especially on long-haul trips of a week or more – so truck manufacturers put noise reduction high on their list of design requirements," explained Gert Proost, engineering manager for On-Road Vehicle Filtration at Donaldson's European development center in Leuven, Belgium. "Meeting interior and pass-by noise targets using physical



Waterfall diagram of spectral data created in LMS Virtual.Lab Acoustics helps engineers to ensure engine pressure pulsations from the turbocharger are sufficiently attenuated by the air intake system.

mock-ups and trial-and-error testing is just too expensive, time-consuming and uncertain, given the huge number of interacting variables."

ACOUSTIC SIMULATION EXPERTISE

The answer, according to Proost, is acoustic simulation that enables engineers to evaluate sound levels and possible noise reduction fixes quickly and easily using computer models. Rather than outsourcing such simulations work to other facilities and putting up with long waits in shuffling project iterations back and forth, the Leuven group decided to bring acoustic simulation in-house. "Doing acoustic simulation ourselves is highly efficient. We can see how sound characteristics vary with slight changes in components, materials and geometries. This gives our engineers tremendous insight into the acoustic behavior of the entire system," said Proost.

Donaldson selected LMS Virtual.Lab

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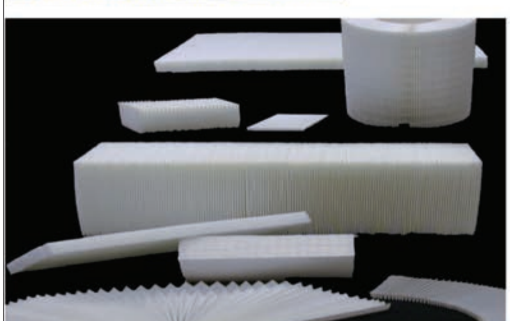

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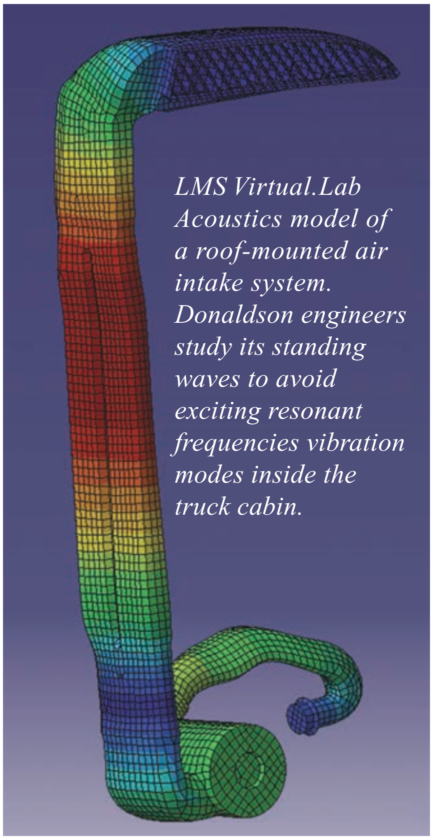
Acoustics from Siemens PLM Software as the acoustics simulation software of choice. The decision was based on reputation and widespread use of the software in the automotive industry, the technical assistance available from the LMS team, and the modeling capabilities of the software in handling airborne as well as structure-born noise and vibrations. Donaldson is currently using the simulation software to develop an air intake system for a major European truck manufacturer aiming to have one of the quietest long-range truck cabs on the market. Donaldson has also been approached by other vehicle manufacturers requesting quotes for system-level designs. "Clearly, ongoing work with the initial truck project will enable us to employ the same approach for future contracts in developing complete air intake systems that produce minimal cab noise," Proost noted. "Siemens has been with us every step of the way with technical assistance to validate models and fine-tune our overall approach."

FINDING, FIXING UNACCEPTABLE NOISES

As the first simulation step, Donaldson engineers represent the air intake system with a boundary element method (BEM) model, a technology particularly well suited to studying airborne noise since the method does not require engineers to go through the tedious task of modeling interior air volumes. This BEM model is used to determine standing-wave frequencies produced in various duct sections. Structure-born vibrations are studied using a coupled finite-element method (FEM) analysis to ensure that standing waves do not excite ducts and other parts of the system to vibrate at resonance.

Next, engineers compute the transfer function of audible noise transmitted from the nozzle to the driver's ear. For this computation,



LMS Virtual.Lab Acoustics model of a roof-mounted air intake system. Donaldson engineers study its standing waves to avoid exciting resonant frequencies vibration modes inside the truck cabin.

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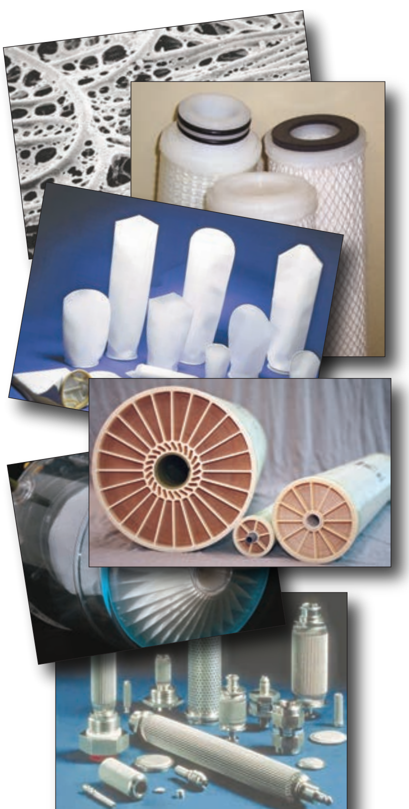

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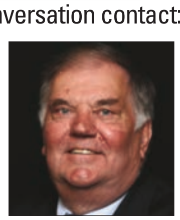

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they set up a low-frequency sound source in the cab and measure the corresponding frequency response at the nozzle with a LMS Test.Lab SCADAS Mobile signal data acquisition and analysis system – used for its easy portability and speed in gathering data and seamless compatibility with LMS Virtual.Lab. This measurement enables engineers to back-calculate the noise transfer function (NTF) – the ability of the air to transfer sound energy from the nozzle to the cab. Finally, the NTF is multiplied by the combined airborne and structure born vibration energy to determine total interior cab noise. The result is a color-coded 3D plot of sound energy distribution in the cab interior to identify any hot spots of sound power density. Engineers can then quickly modify the intake design with resonators, stiffeners and other modifications to eliminate resonances. They almost immediately see the results of these modifications. A few rounds of these changes are generally all it takes to optimize cab noise levels.

Near the end of development, the Donaldson engineers use a LMS SCADAS Vibco vibration control system for accelerated fatigue-life shaker tests. This demonstrates in just a day or two the ability of the air intake to withstand the vibration it will likely experience over a lifetime on the road.

VALUE OF PREDICTIVE PROCESSES

"Using a predictive process based on LMS Virtual.Lab Acoustics, our engineering teams can perform studies in a few hours that would take months or even years and cost tens of thousands of Euros in physical mock-ups," noted Proost. "This approach gives us the capabilities we need to develop complete air intake systems optimized to meet rigorous noise limits. Our cutting-edge acoustics know-how has certainly become a critical competitive advantage and helps us gain research and development contracts up the supply chain for vehicle manufacturers around the world."

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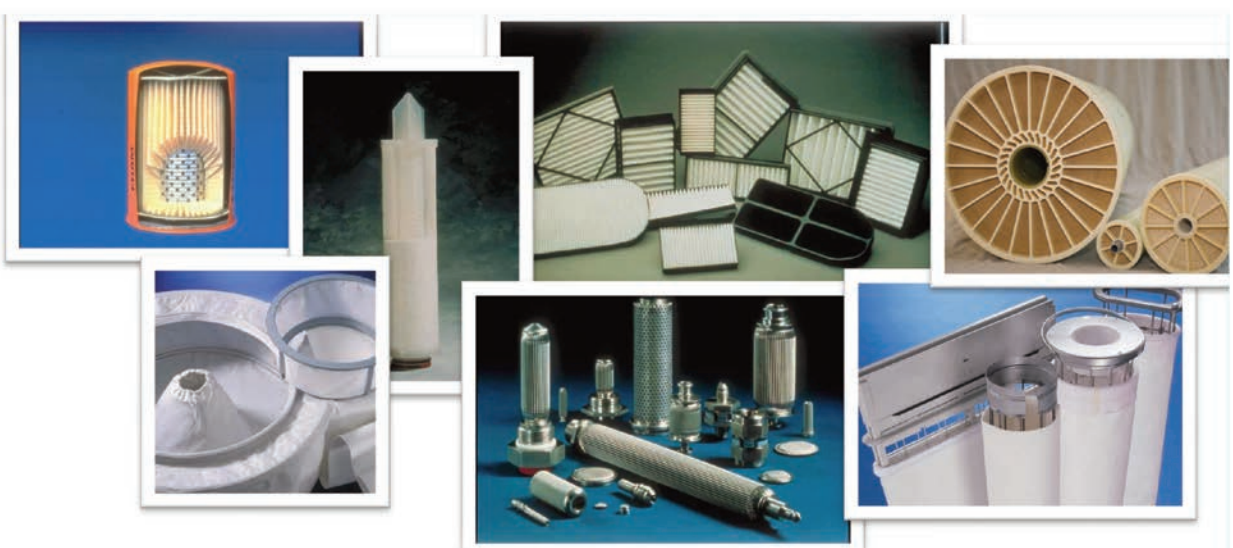

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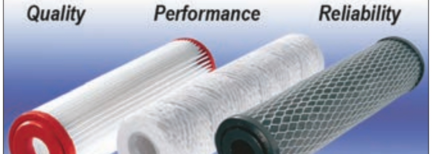

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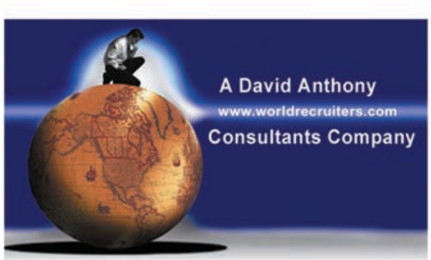

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