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Myron L Company: In-Cell Titrations Make Real-Time Field Analysis Possible

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The Filtration Term "Bypass" Defined

By James J. Joseph, Joseph Marketing, Williamsburg VA

Whenever filtration engineers of different countries talk to each other about the filtration technology they already have a familiar language because of the common words and terms. There are terms such as micron, media, and flow rate per filter area to name just a few. The actual words may need translating between different languages but their applicability is immediately understood. The irony is that those involved are keenly aware of the potential problem with highly technical terms and diligent enough to define them to minimize misunderstanding.

However, sometimes simple terms go unnoticed and the misapplication of the phrase could create a gap in transferring information. This even happens with the same language. There are terms, which may mean one thing in one filtration sector and mean something else in another area. One obvious term is the word "bypass." This common jargon has four different applications in this industry.

Therefore, this article offers the four definitions of the term "bypass", which includes:

1. An unwanted migration of contaminated liquid
2. Purposeful rerouting of contaminated liquid around a filter
3. A technique for system design
4. A diverting path to send liquid through a different route

The commonality of the four uses implies that there is a deviation from the main or normal flow of a filtration system. That is why the word "bypass" is so popular. However, the deviation is for different reasons.

UNWANTED MIGRATION

Undesirable migration is where a liquid can flow through an open media, leaks around the edge seal of a sheet of the media as it is positioned in a flat bed or plate and frame filter, trickles through the end caps of a cartridge filter, bleeds around the retaining ring of a bag filter, or oozes through the manifold of screen filters. Figure 1 shows a bag filter where the retaining ring was not seated properly. This allows contaminated liquid to leak into the clean liquid chamber.

PURPOSEFUL REROUTING

Rerouting the flow may be desirable on critical installations where a filtration device has a potential of becoming loaded to a point where its effluent rate of flow is throttled back to an undesirable level. It is a safety measure to prevent the loss of fluid flow when a filter is blinded and allows dirty liquid to enter the clean liquid chamber because the lack of flow could be dangerous to the operator, process, or equipment. Dirty liquid is better than no liquid.

This bypass technique can be an automatic feature to direct the liquid around the blinded media so the operation is not starved. This technique is usually found in pressure filters where self cleaning is not a feature in the design. Cartridge filters may have an external pressure relief valve, which opens at a critical set point. Some vessels have the pressure relief valve built into the housing as depicted in Figure 2.

FIGURE 1: UNWANTED MIGRATION

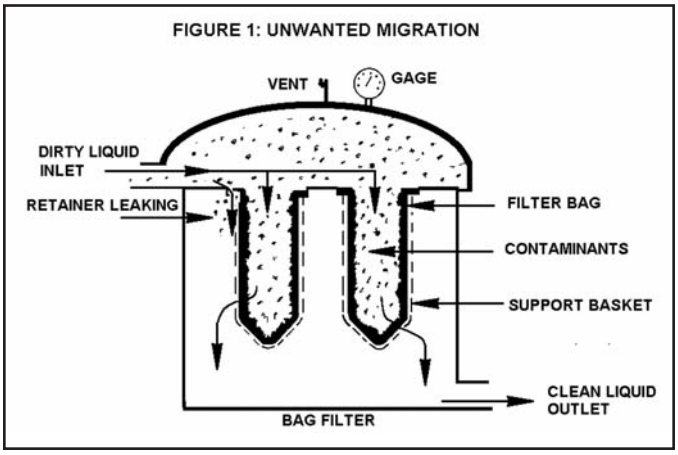
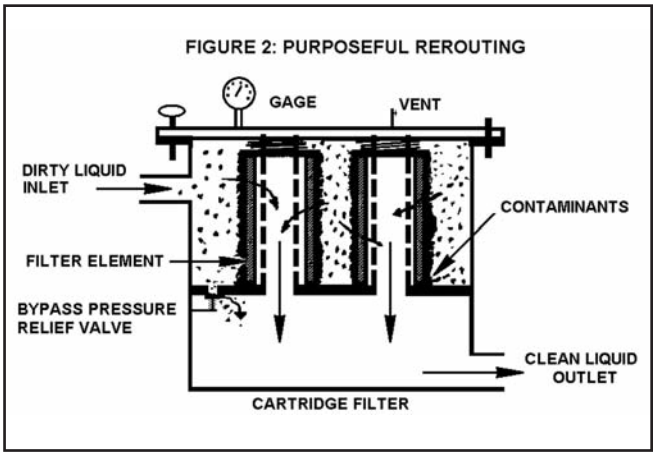


FIGURE 2: PURPOSEFUL REROUTING



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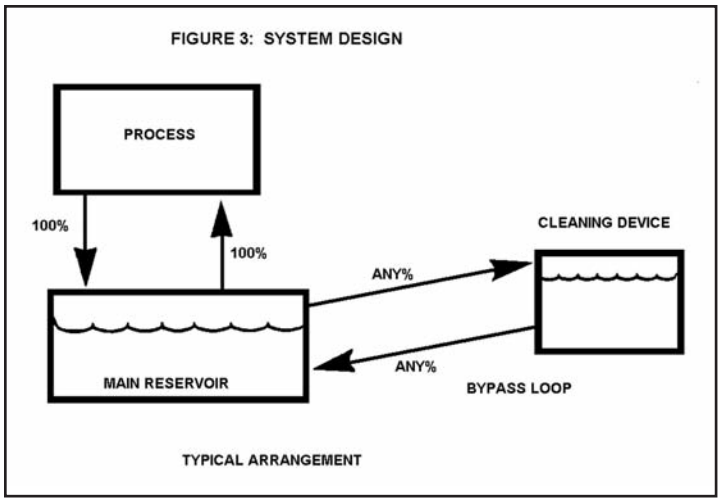


SYSTEM DESIGN

Many filtration schemes establish an independent "loop" where a cleaning device, regardless of its design, works "from and to" a specific reservoir. Since the cleaning device is dedicated to a given reservoir its selection and size are a matter of turnover rate of the volume of fluid in the reservoir. Many systems utilize this concept with their initial design, such as hydraulic systems and closed loop cooling water systems. Figure 3 shows a simple but typical arrangement. This type of system is usually installed on applications where a contaminant load is relatively light, or the application does not need 100 percent filtration.

Also, it is an effective tool to retrofit existing systems where the full flow system can be improved without a major renovation of the existing system. The bypass loop can work off the clean liquid reservoir to "polish" the fluid by removing finer particulate.

Bypass systems are now usually referred to as "side arm", "kidney loop", or "parallel leg" to avoid the confusion of the bypass term.

DIVERTING PATH

Many process systems are designed to send fluid around a particular operation when the specific operation is in an idle mode or shut down for any number of reasons. The flow is not interrupted but diverted around the operation. The logic is to keep the supply of fluid flowing for two main reasons:

The total system flow is maintained at the desired pressure so other operations on the line are not affected by the change.

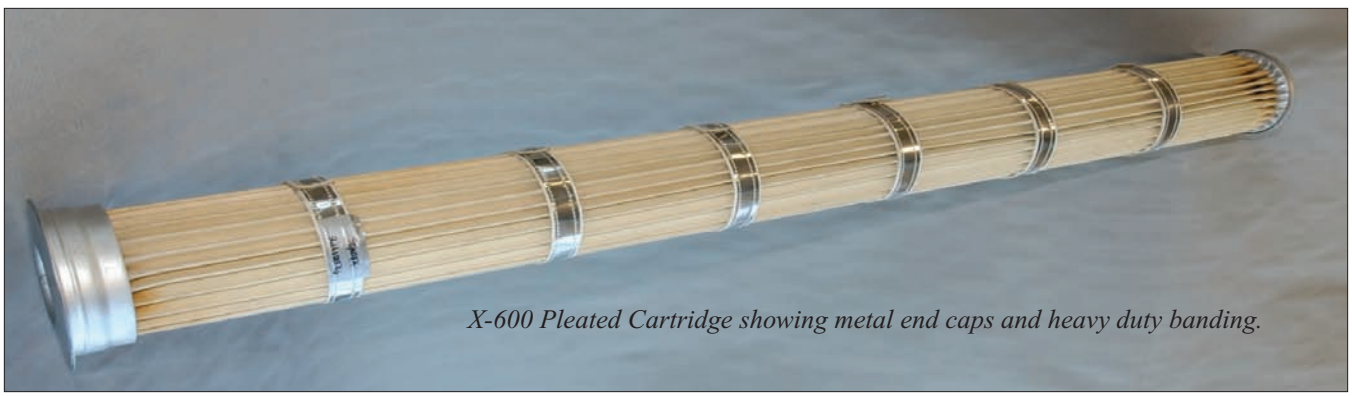
The operation can resume immediately without the need to wait for the lines to fill again.

CONCLUSION

As it can be seen, with four different terms of "bypass" it is important to define the intended meaning and show its logic so that communications between designer, supplier, and user will be complete and misunderstandings will be minimized.

Increased Baghouse Capacity and Improved Filter Performance from Pleated Cartridges

By John Courtenay, MQP Limited and Dr. Luc Parent, Sefar



X-600 Pleated Cartridge showing metal end caps and heavy duty banding.

The Xtreme X-600 pleated cartridge is a new concept in baghouse filter elements capable of operating continuously at temperatures up to 250˚C. It offers significant improvements in baghouse capacity and filter performance compared with standard filters. The X-600 has been developed by Sefar BDH, a Canadian subsidiary of Sefar group of Switzerland. Sefar BDH specializes in both low temperature and high temperature filtration.

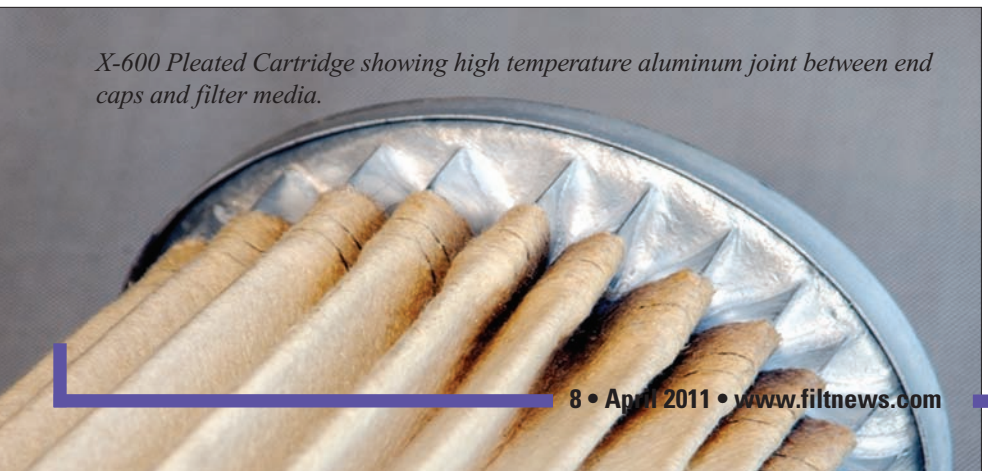
BENEFITS

The range of benefits from using the X-600 can be summarized as follows:

- Increase baghouse capacity by up to 25%
- Up to 40% reduction in pressure drop
- Lower air to cloth ratio
- Improvement in filtration efficiency
- Longer life
- Reduced cleaning pulse rate
- Decrease in downtime
- Reduction in labor costs

THE PRODUCT

The unique design features of the X-600 cartridge, which bring about these performance improvements are the manner in which the joints between the filter media and the end caps are formed, using a liquid aluminum potting alloy and a doubling up of the available filter cloth area in each cartridge.



X-600 Pleated Cartridge showing high temperature aluminum joint between end caps and filter media.

The X-600 cartridge has:

- 100% metal end caps
- Unique high temperature aluminum jointing of end caps to media
- Heavy duty construction bands
- Felt of Fiber glass media
- PTFE membrane on

Existing baghouse filter units can be upgraded to X-600 pleated cartridges without any modifications being required, by simple retro fitting the new cartridges into the existing tube plates.

INDUSTRIAL EXPERIENCE

The X-600 Pleated Cartridge was first introduced for a titanium producer in 2004 and since November 2005 has been in continuous production use on all four compartments bag houses with each having 960 filters treating 100,000 m3/hr of waste gas. The industrial experience with rotary kiln calcinations and a micronizer for reducing particle size of TiO2 can be summarized as follows:

CASE HISTORY I

Ore of TiO2 and Fe2O3 is calcined at 1200˚C in a rotary kiln at a rate of

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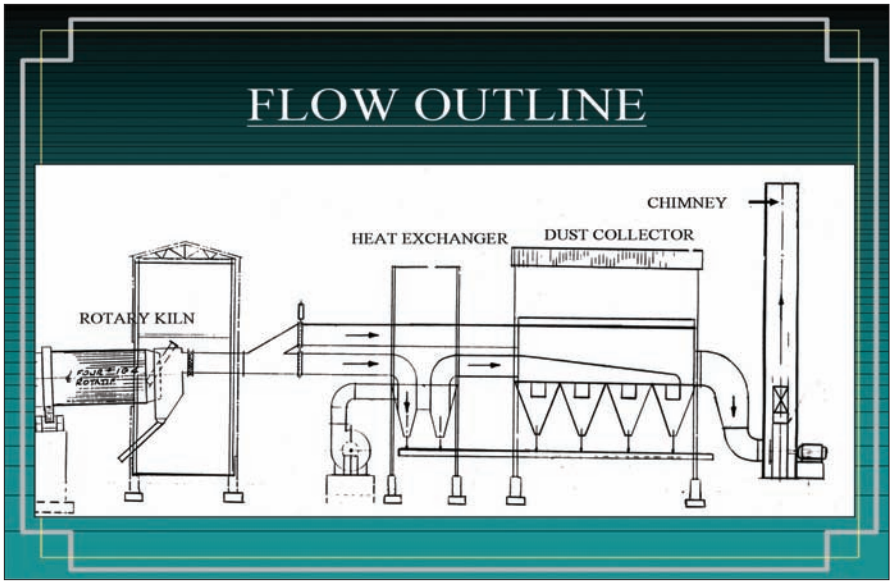

Figure 1. Flow outline of Rotary Kiln Dust Collectors

	Original bags of Fiberglass with E-PTFE Membrane	New X-600 Pleated Cartridge Elements (44 pleats of 25 mm of pleat depth)
Baghouse type	Pulse jet	Pulse jet
Bags dimensions	140 x 4295 mm	140 x 1640 mm
Surface of 1 bag	1.95 m2	3.62 m2
Number of bags	960	960
Air flow	100,000 m3/h	100,000 m3/h
Air-to-cloth ratio	0.89 m/minute	0.48 m/minute
Δ Pressure	1.5-3.0 kPa	0.6-1.5 kPa
Temperature	220° C	220° C
Dust composition	TiO2, Fe2O3, SiO2	TiO2, Fe2O3, SiO2
Mean particle size	5 µ	5 µ
Gas composition	N2, CO2, CO, SO2(1000 PPM)	N2, CO2, CO, SO2(1000 PPM)
Cleaning frequency	8 seconds	On demand
Service time	3-12 months	> 24 months
Dust load (g/m3)	4	4

Table 1. Comparative data for rotary kiln dust collection

100 MT per hour. At the outlet of the kiln, the gas is cooled to 240°C by mixing with ambient air and then passed into a bag house (Figure1).

The bags originally being used in the baghouse were Fiberglass with E-PTFE Membrane and there were problems with the bags short life span, lack of capacity for the rotary kilns, and excessive emissions and abrasion damage to the bags.

The original bags were replaced with X-600 Pleated Cartridges and comparative operating data are shown in Table1.

The overall objective of introducing X-600 Pleated Cartridges was to reduce emissions to less than 15 kg/h for the total of the four baghouses. This goal was satisfactorily achieved with emissions down to 7 kg/h.

Other major benefits were:

- Increased capacity of dust collectors
- Pressure drop reduced
- Life of baghouse filters increased to two years
- Pulse jet cleaning frequency reduced
- Capacity of Rotary Kiln Operation increased

CASE HISTORY 2

TiO2, which is used as a pigment in paint, is obtained by treating an ore, containing TiO2 and Fe2O3 and impurities with chlorine, which results in the production of TiCl4 as a liquid that is easily separated from the impurities. The liquid is then evaporated and fed into an oxygen rich flame at more than 1500°C.

Some grades of finished product require finer TiO2 particles. For these applications, the TiO2 is projected at high velocity together with steam on a steel plate. This reduces the particle size. This part of the plant is referred to as the micronizer and the final ground product then is separated from steam using a baghouse.

The bags originally used in the baghouse for this process were Aramid.

A major operating problem was the short life span of the bags, which needed to be changed every six weeks at the plant, which has four baghouses. In an effort to overcome this problem the original bags were replaced with X-600 Pleated Cartridges with PTFE Membrane.

The principal objectives were to increase baghouse lifetime, decrease downtime and reduce cost of manpower for bags replacements.

Comparative operating data is shown in Table 2.

The target at the micronizer plant was to get a minimum 1-year baghouse lifetime. The current installation of X-600 cartridges has already been in operation for more than 16 months with no signs of deterioration.

Summary of benefits:

- Increase in baghouse life
- Reduction in labor costs
- Decrease in downtime

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–Jerry Lynch - President
Sigma Design Company, L.L.C.
Springfield New Jersey

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–Nathan Capps
Beam Global Spirits & Wine

For more information and registration go to:
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	Original bags of Aramid	New X-600 Pleated elements, PTFE membrane (44 pleats of 25 mm pleat depth)
Baghouse type	Pulse jet	Pulse jet
Bags dimensions	150 x 3048 mm	150 x 1640 mm
Surface of 1 bag	1.44 m2	3.62 m2
Number of bags	135	135
Air flow	5400 kg of steam/ hour	5400 kg of steam/ hour
Air-to-cloth ratio	Not known	Not known
Pressure	2.0 -3.7 kPa	0.2 -1.0 kPa
Temperature	170° C	170° C
Dust composition	TiO2	TiO2
Mean particle size	0.5-1.0 µ	0.5-1.0 µ
Gas composition	Air and water	Air and water
Cleaning frequency	4 seconds	8 seconds
Service time	6 weeks	> 52 weeks (still in operation)
Dust load	2800 kg/h	2800 kg/h

Table 2. Comparative Data for Microniser Dust Collection

- Decrease in pressure drop
- Reduced pulse jet cleaning frequency

Since then the X-600 Pleated Cartridge has been utilized in a number of other industrial applications, elsewhere, including an aluminum smelter anode bakehouse, waste incineration, soil desorption, and Coke Calcination.

EVALUATING PLEATED CARTRIDGES

Extreme X-600 cartridges are produced by Sefar. MQP, based in the U.K., is an official representative for marketing in Europe and the Middle East.

Both companies provide expert technical consultancy on any proposed application to assess performance and potential benefits. Once an application has been positively evaluated several X-600 cartridges would be supplied for insertion for an initial assessment over a period of 3 months.

The cartridges would then be returned for a detailed assessment of wear and cleaning characteristics in the particular application environment.

If performance had been satisfactory the next stage would be to equip one complete compartment of the baghouse and monitor all characteristics including pressure drop, life, emissions and cleaning frequency.

For more information visit:
Sefar: www.sefar.ca
MQP: www.mqpltd.com

AFS to Offer 11 Short Courses in Louisville

The American Filtration and Separations Society (AFS) is offering filtration short course training on Monday, May 9, 2011 in Louisville, Kentucky. The following day marks the beginning of AFS 24th Annual Conference - May 10-12, enabling visitors to take a short course and stay for the conference.

The short courses are targeted at anyone with customers asking for filter advice, such as companies with customer services reps, sales reps or technical staff that need more knowledge about filtration technology.

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In-Cell Titrations Make Real-Time Field Analysis Possible

By Heather Rekalske, Myron L Company

Figure 1: The New 9P Titration Kit from Myron L Company features conductometric titrations for on-the-spot analysis of hardness, alkalinity and saturation index.

Now it's possible to get fast accurate alkalinity, hardness and LSI titrations in the field with the Ultrameter III 9P Titration Kit – the next generation of water quality monitoring equipment from the Myron L Company.

The Ultrameter III 9P is based on the tried and tested design of the Ultrameter II 6P and measures conductivity, resistivity, TDS, pH, ORP, free chlorine and temperature quickly and accurately. The 9P also features exciting new parameters that allow the user to perform titrations in the field. The Myron L Company has developed a unique method of performing alkalinity, hardness and LSI titrations that makes field monitoring fast and feasible.

HOW DOES IT WORK?

The 9P titrations are based on conductometric titration methods that are possible with the 9P's advanced conductivity cell and microprocessor based design. Titrations are chemically equivalent to standard methods using colorimetric techniques, but replace color change identification of equivalence

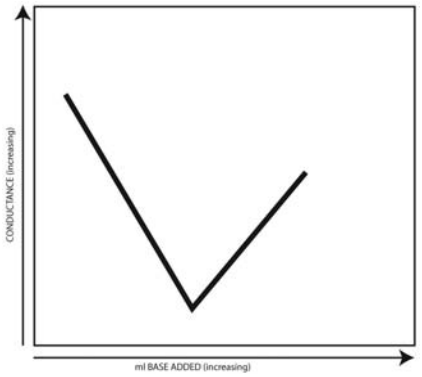

Figure 2: The titration of a strong acid with a base yields a conductivity plot with a clearly defined equivalence point.

Figure 3: The Ultrameter III 9P gives a numerical digital reading that requires no interpretation, while colorimetric tests require the user to determine the endpoint by color change, which can sometimes be missed while trying to keep track of reagent additions.

points with changes in conductivity, thereby replacing a subjective, qualitative assessment with a quantitative one. This means the instrument determines the equivalence point instead of the user, and the method of analyzing the equivalence point is objective, rather than subjective.

CONDUCTOMETRIC TITRATION

A conductometric titration is performed just like a colorimetric titration, only the equivalence point is determined by a change in conductivity rather than a change in color. This is based on the fact that changes in ionic concentration that occur as constituents react with reagents change the electrical conductivity of the solution.

A simple example can be given of the titration of a strong acid with a strong base. The acid solution, before the addition of the base, has a very high conductance owing to the concentration and mobility of the small hydrogen ions.

With the addition of the base, the hydroxide reacts with the hydrogen to form water, thus reducing the hydrogen ion concentration and effectively lowering the conductivity of the solution. The conductivity continues to decrease until all the hydrogen ions are consumed in the reaction, but then sharply increases with the next addition of base, which contains highly conductive hydroxide ions. The solution conductivity then continues to increase with each base addition. The equivalence point in this example would be a clearly defined minimum point of lowest conductivity (see Figure 2).

Not all solutions will give a plot with an equivalence point that is as easy to distinguish as the sharp upturn found in a strong acid-base titration, however. The 9P plots several reagent additions beyond any changes in conductivity and matches the derived curve to the behavior of solutions of known concentration.

STANDARD METHOD?

(Standard method comparison to methods listed in the Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association, the American Water Works Association, and the Water Environment Association).

Myron L Company's conductometric titration methods are chemically equivalent to standard methods that use the same procedure, but with pH indicators. That means that they use the same reagents in the same sequence with the same theoretical approach. The difference lies in the 9P's ability to determine the equivalence point based on numerical data, rather than subjective observation of a color change.

The alkalinity titration is modeled after standard method 2320. The sample is titrated with sulfuric acid and conductivity changes are recorded at each titration point.

The hardness titration is modeled after standard method 2340. To reduce the affects of high alkalinity in the form of bicarbonate, acid is first added to the sample. This shifts the bicarbonate toward carbonic acid, then carbon dioxide (reference the carbonic acid equilibrium), which is gassed off the sample. The sample is buffered above pH 10 (effectively pH 12) by the addition of sodium hydroxide. EDTA reagent is then added incrementally, with conductivity measured after each addition.

The LSI titration uses a simplified version of the thermodynamic equations for the determination of the scaling tendency of water developed in 1936 by Dr. Wilfred Langelier. The user simply titrates for alkalinity and hardness, then measures pH and temperature, and the 9P generates the saturation index value automatically.

CONDUCTOMETRIC VS. COLORIMETRIC

The benefits of determining the equivalence points by conductometric titrations are that the user does not have to interpret any results. The 9P does it automatically, using objective measurements. And the 9P is a faster method. For example, a typical colorimetric titration for hardness can take up to 30 drops of reagent, while the 9P method for the same concentration only requires 6-8 drops. Colorimetric distinctions are sometimes

Figure 4: The 9PTK comes with everything you need to analyze Conductivity, Resistivity, TDS, pH, ORP, Free Chlorine, Temperature, Alkalinity, Hardness, and LSI in the field.

hard to make, as well, especially when adding reagents drop by drop while trying to carefully observe the precise point at which the color changes – and that can lead to inaccurate data (see Figure 3). This is especially true in colored or turbid solutions.

The conductometric method can also be used with very dilute solutions or for solutions for which there is no suitable indicator. The conductometric titration method gives empirical results that are calculated for the user, eliminating potential sources of error. And the measurements can be stored in memory for later data transfer using the optional U2CI software and bluDock™ Bluetooth® hardware installed on the 9P. This makes data analysis and reporting seamless.

OTHER FEATURES

Alkalinity, hardness, pH and temperature values used to compute the saturation index of a sample can be manipulated in the LSI Calculator function, allowing the user to perform on the spot analysis of water balance scenarios. They can use historical or theoretical data to populate the required values in the calculator.

The 9P titration kit comes with all required accessories, reagents, and calibration solutions (see Figure 4). Call the Myron L Company to see how the 9P can streamline field testing.

For more information contact:

Myron L Company | 2450 Impala Drive | Carlsbad, CA 92010-7226
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Email: info@myronl.com | Website: www.myronl.com

Membrane Treatment Technologies for Water Reuse

By Peter S. Cartwright, PE

Table I, Distribution of World Water Supply (cubic miles)

	FRESH	SALINE	TOTAL
Rivers and streams	300		
Freshwater lakes	30,000		
Salt lakes and inland seas		25,000	
Total surface water	**30,300**	**25,000**	**55,300**
Soil moisture and seepage	16,000		
Underground water to ½ mile depth	1,000,000		
Underground water to below ½ mile	1,000,000		
Total ground water	**2,016,000**		**2,016,000**
Glaciers and ice caps	7,000,000		
Oceans		317,000,000	
Total world water supply	**9,046,300**	**317,000,000**	**326,071,300**

Whereas the total quantity of water on this planet is more or less fixed, its quality is deteriorating, because we have been contaminating it for thousands of years, with little concern for the consequences.

Drinking water regulations continue to increase water quality standards, and industrial and commercial activities are requiring higher quality water in many applications. Due to population growth, drinking water and agricultural quantity demands are also steadily increasing.

Industries, in general, are very poor stewards of water conservation. Most water brought into the plant is used only once, even though that use may have had very little impact on water quality.

In most of the industrialized world, many have labored under the misconception that their water supply was inexhaustible as well as inexpensive. This cost aspect has been exacerbated by the fact that, in many areas, the price of water has been partially subsidized by local government.

Table I indicates the distribution of the world's water resources:

The issue we are faced with is the availability of water of sufficient quality. An analogy is that if all the world's water were to fit into a gallon jug, the fresh water available for use would equal only about 1 tablespoon.

Today, about 20% of the world's population is without clean water, and it is expected that, without drastic measures, half of the people on this planet will suffer from severe water shortages by 2050.

The U.N. estimates that over ten million people a year die from drinking polluted water, mostly children.

Across the United States, 39% of water use goes to energy production. Farms use another 40%, and manufacturing an additional 11%. Together, these three sectors use about 300 billion gallons of fresh water every day.

As probably the largest "water-wasting" country in the world, each American uses, on average, 100 gallons of water a day, easily twice the quantity of the average European.

- Two-thirds of the water used in an average American home is used in the bathroom: 25-40 gallons/5 minute shower, 1½ - 7 gallons/ toilet flush. It takes almost 800 gallons of water to grow the food for one person for one day.
- U.S. households turn on water faucets an average of 70 times daily. It is estimated that as much as 50% of the water that families use could be saved by implementing simple conservation methods.
- 1 bottle of beer requires 470 gallons of water. 1 gallon of gasoline requires 7-10 gallons of water, while 1 gallon of ethanol uses 5-7 gallons of water.
- Agriculturally, it takes 100 gallons of water to grow one watermelon.
- In industry, it takes over 60,000 gallons to produce one ton of steel, and 39,000 gallons for one car.
- About 500,000 tons/day of pollutants pour into U.S. lakes and rivers, with 11% of it from storm water runoff.

Table II, Water Contaminants

Class	Examples
Suspended solids	Dirt, clay, colloidal materials, silt, dust, insoluble metal oxides and hydroxides
Dissolved organics	Hydrocarbons (emulsified and/or dissolved), synthetic organic chemicals, humic acids, fulvic acids
Dissolved ionics (salts)	Sodium chloride, heavy metals, silica, arsenic, nitrate, chloride, carbonates
Microorganisms	Bacteria, viruses, protozoan cysts, fungi, algae, molds, yeast cells
Gases	Hydrogen sulfide, methane, sulfur dioxide, carbon dioxide, natural gas

A critical and necessary activity to address the looming shortages of acceptable quality water is water recovery and reuse.

Water reuse is the general term applied to the act of recovering water from a process, treating (converting) and reusing it in the same process, or another one, before discharging it.

CONTAMINATION ISSUES

The key to industrial water reuse is to have an arsenal of technologies available to efficiently remove hazardous or undesirable contaminants from the water supply. There is no single technology that will efficiently remove all classes of contaminants; however, for the past century or so, there have been significant developments in treatment technologies capable of effectively reducing the concentration of virtually any contaminant down to acceptable levels for any water use requirement.

It is important to keep in mind that no treatment will remove all of any contaminant from water supplies.

Recognizing that all water treatment involves removing (or inactivating) contaminants, it is necessary to understand what these contaminants are.

To that end, it is possible to group the contaminants in five specific classes, as indicated in Table II.

MEMBRANE TECHNOLOGIES

The membrane separation technologies of microfiltration, ultrafiltration, nanofiltration and reverse osmosis possess characteristics, which make them attractive as water reuse processes. These include:

- Continuous process, resulting in automatic and uninterrupted operation
- Low energy utilization involving neither phase nor temperature changes
- Modular design – no significant size limitations
- Minimal moving parts with low maintenance requirements
- No effect on form or chemistry of contaminants
- Discrete membrane barrier to ensure physical separation of contaminants
- No chemical addition requirements to effect separation

It is virtually impossible to accurately design a wastewater treatment system utilizing membrane technologies without a complete and thoroughly comprehensive testing program. This is required to identify the best membrane polymer and element configuration, and to optimize the system design and operating conditions.

Membrane technologies are based on a process known as "crossflow" or "tangential flow" filtration, which allows for continuous processing of liquid streams. In this process, the bulk solution flows over and parallel to the membrane surface, and because the system is pressurized, water is forced through the membrane and becomes "permeate." The turbulent flow of the bulk solution over the surface minimizes the accumulation of particulate matter. Figure 1 illustrates conventional filtration compared to crossflow filtration.

The crossflow membrane separation technologies of microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) are defined by some membrologists on the basis of pore size. Other experts prefer to use definitions based on the removal function, as follows:

Microfiltration is utilized to remove

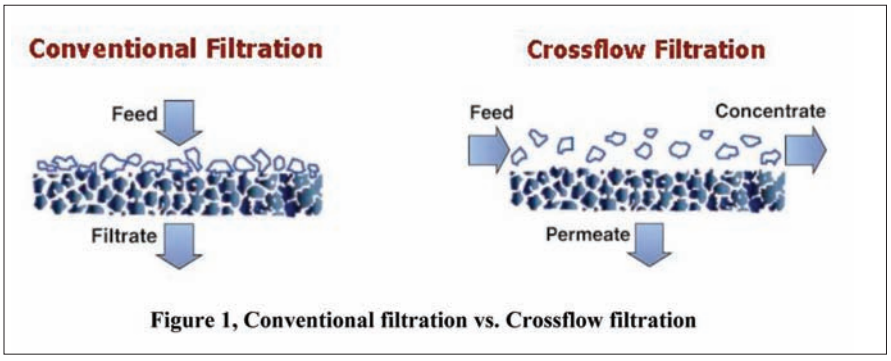


Figure 1, Conventional filtration vs. Crossflow filtration

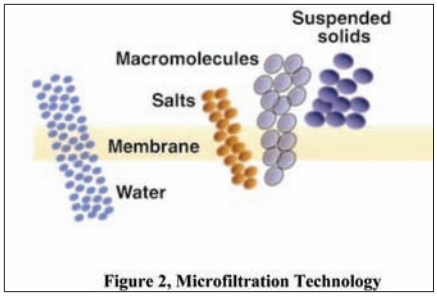


Figure 2, Microfiltration Technology

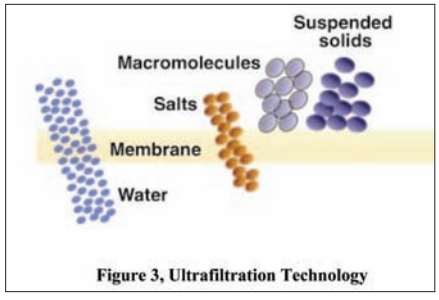


Figure 3, Ultrafiltration Technology

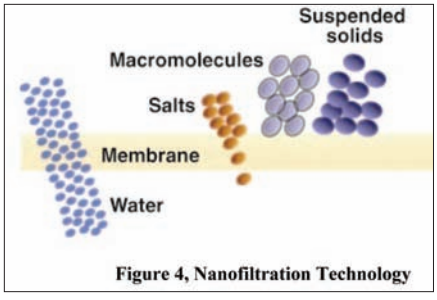


Figure 4, Nanofiltration Technology

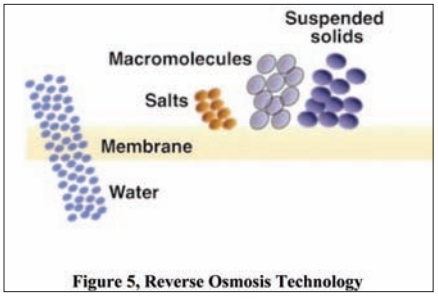


Figure 5, Reverse Osmosis Technology

submicron suspended materials on a continuous basis. The size range is from approximately 0.01 to 1 microns (100 to 10,000 angstroms). Microfiltration is illustrated in Figure 2.

Ultrafiltration is the membrane process which removes dissolved non-ionic solute, typically organic materials (macromolecules). Ultrafiltration membranes are usually rated by "molecular weight cutoff" (MWCO), the maximum molecular weight of the compound that will pass through the membrane pores into the permeate stream. Ultrafiltration pore sizes are usually smaller than 0.01 micron (100 angstroms) in size. Ultrafiltration is depicted in Figure 3.

The above processes (MF and UF) separate contaminants on the basis of a "sieving" process; that is, any contaminant too large to pass through the pore is rejected and exits in the concentrate stream.

Nanofiltration can be considered "loose" reverse osmosis. It rejects dissolved ionic contaminants but to a lesser degree than RO. NF membranes reject a higher percentage of multivalent salts than monovalent salts (for example, 99% vs. 20%). These membranes have molecular weight cut-offs for non-ionic solids below 1,000 daltons. Nanofiltration is illustrated in Figure 4.

Reverse osmosis produces the highest quality permeate of any pressure driven membrane technology. Certain polymers will reject over 99% of all ionic solids, and have molecular weight cut-offs in the range of 50 to 100 daltons. Figure 5 illustrates reverse osmosis.

Both NF and RO membranes reject salts utilizing a mechanism that is not fully understood. Some experts endorse the theory of pure water preferentially passing through the membrane; others attribute it to the effect of surface charges of the membrane polymer on the polarity of the water. Monovalent salts are not as highly rejected from the membrane surface as multivalent salts; however, the high rejection properties of the newer thin film composite RO membranes exhibit very little differences in salt rejection characteristics as a function of ionic valance. As indicated earlier, this difference is significant with NF membranes.

In all cases, the greater the degree of contaminant removal, the higher the pressure requirement to effect this separation. In other words, reverse osmosis, which separates the widest range of contaminants, requires an operating pressure typically an order of magnitude higher than microfiltration, which removes only suspended solids.

The water passage rate through the membrane to generate treated water (permeate) is known as "flux rate." It is a function of applied pressure, water temperature, and in the case of NF and RO (and to a limited extent, UF), the osmotic pressure of the solution under treatment. Flux rate is usually measured as GFD (gallons per square foot per day) or LMD (liters per square meter per day).

Increasing the applied pressure will increase the permeate rate; however, a high flow of water through the membrane will promote more rapid fouling. Membrane element manufacturers usually provide limits with regard to maximum applied pressures to be used as a function of feed water quality.

Heating the water will also increase the permeate rate, but this requires significant energy and is generally not considered practical.

Table III summarizes the various properties and other features of these technologies.

DEVICE CONFIGURATIONS

To be effective, membrane polymers must be packaged into a configuration commonly called a "device" or "element." The most common element configurations are: Plate and Frame,

Tubular, Hollow (Capillary) Fiber, and Spiral Wound.

The element configurations are described and illustrated in Figure 6.

Plate and Frame. Sheet membranes are stretched over a frame to separate the layers and facilitate collection of the permeate, which is directed to a collection tube.

Tubular. Manufactured from ceramics, carbon, stainless steel, or a number of thermoplastics, these tubes have inside diameters ranging from ¼ inch up to approximately 1 inch (6 to 25 mm). The membrane is typically coated on the inside of the tube and the feed solution flows under pressure through the interior (lumen) from one end to the other, with the permeate passing through the wall and collected outside of the tube.

Hollow (Capillary) Fiber. These elements are similar to the tubular element in design, but are smaller in diameter, and are usually unsupported membrane polymers or ceramics. In the case of polymeric capillary fibers, they require rigid support on each end provided by an epoxy "potting" of a bundle

Table III, Membrane Technologies Compared

Feature	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Polymers	Ceramics, Sintered metals, Polypropylene, Polysulfone, Polyethersulfone, Polyvinylidene fluoride, Polytetrafluoroethyliene	Ceramics, Sintered metals, Polypropylene, Polysulfone, Polyethersulfone, Polyvinylidene fluoride	Thin film composites, Cellulosics	Thin film composites, Cellulosics
Pore Size Range (microns)	0.1 - 1.0	0.001 - 0.1	0.0001 - 0.001	<0.0001
Molecular Weight Cutoff Range (Daltons)	>100,000	1,000 - 100,000	300 - 1,000	50 - 300
Operating Pressure Range (psi)	<30	20 - 100	50 - 300	225 - 1,000
Suspended Solids Removal	Yes	Yes	Yes	Yes
Dissolved Organics Removal	None	Yes	Yes	Yes
Dissolved Inorganics Removal	None	None	20-95%	95-99+%
Microorganism Removal	Protozoan cysts, algae, bacteria*	Protozoan cysts, algae, bacteria*, viruses	All*	All*
Osmotic Pressure Effects	None	Slight	Moderate	High
Concentration Capabilities	High	High	Moderate	Moderate
Permeate Purity (overall)	Low	Moderate	Moderate-high	High
Energy Usage	Low	Low	Low-moderate	Moderate
Membrane Stability	High	High	Moderate	Moderate

** Under certain conditions, bacteria may grow through the membrane.*

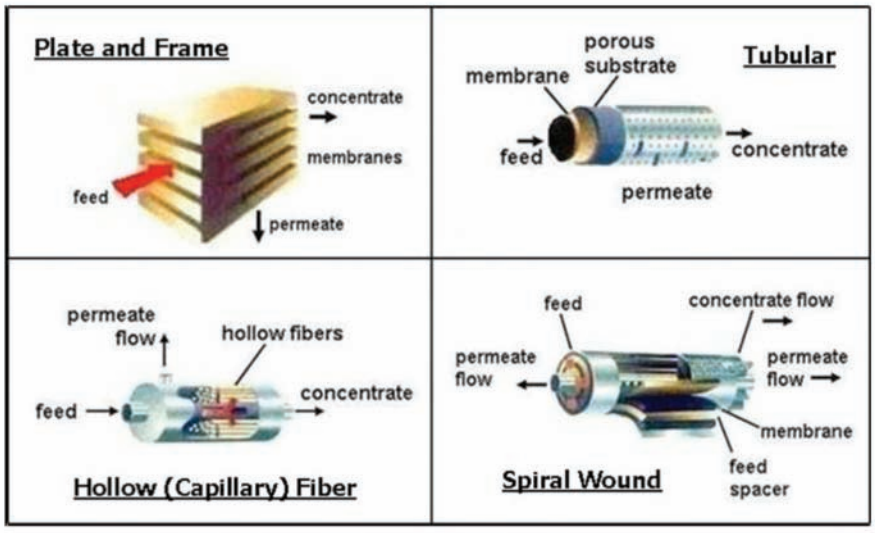


Figure 6, Membrane Element Configurations

Table IV, Membrane Element Configuration Comparison

Element Configuration	Packing Density *	Fouling Resistance **
Plate & Frame	Low	High
Tubular	Low	High
Hollow (Capillary) Fiber	Medium	Moderate
Spiral Wound	Medium	Low

** Membrane area per unit volume of element*

*** Tolerance to suspended solids*

of the fibers inside a cylinder. Feed flow is either down the interior of the fiber ("lumen feed") or around the outside of the fiber ("outside-in").

Spiral Wound. This element is constructed from an envelope of sheet membrane wound around a permeate tube that is perforated to allow collection of the permeate. Water is purified by passing through one layer of the membrane and, following a spiral path, flows into the permeate tube. It is by far the most common configuration in water purification applications, but generally requires extensive pretreatment in wastewater applications.

From the perspective of cost and convenience, it is beneficial to pack as much membrane area into as small a volume as possible. This is known as "packing density." The greater the packing density, the greater the membrane area enclosed in a certain sized device, and generally the lower its cost. The downside of the high packing density membrane elements is their greater propensity for fouling. Table IV compares the element configurations with regard to their packing densities and fouling resistances.

SYSTEM PERFORMANCE

The vast majority of membrane system failures occur as the result of membrane fouling. This fouling is usually caused by one or more of the following mechanisms:

- Suspended solids in the feed stream resulting from incomplete feed water filtration
- Precipitation of insoluble salts or oxides resulting from concentration effects within the membrane device
- Biofilms resulting from microbiological activity

These mechanisms cause the membrane surface to become coated with

Table V, Effect of Recovery on Concentration

$$C_c \approx \frac{C_F}{1 - \text{Recovery}} = XC_F$$

$$X = \frac{1}{1 - \text{Recovery}} = \text{Concentration Factor}$$

Percent Recovery	Concentration Factor
33%	1.5
50%	2
67%	3
75%	4
80%	5
90%	10
95%	20
97.5%	40
98%	50
99%	100

fouling materials that build up in layers. As the layer thickness increases, the crossflow rate and resulting turbulence across the membrane surface (and immediately adjacent to it) is reduced, thereby encouraging more settling of suspended solids and increasing the fouling layer thickness, which further slows the rate of permeate flow through the membrane – a vicious cycle.

With nanofiltration and reverse osmosis membranes, which reject ionic contaminants, fouling usually creates a phenomenon known as "concentration polarization". The fouling layers inhibit the free movement of contaminants in the feed stream away from the membrane surface via turbulent flow, and as salts are rejected from the membrane, their concentration at the surface is higher than in the bulk solution (that portion above the fouling layer).

Since ionic rejection is always a percentage of the salts concentration at the surface of the membrane, the permeate quality decreases as a result of concentration polarization, and this phenomenon may actually indicate the presence of foulants before a reduction in permeate rate is detected. The increased salts concentration at the membrane surface also promotes precipitation of those salts whose solubility limit is exceeded. In these cases, the addition of an antiscalant chemical will help minimize precipitation.

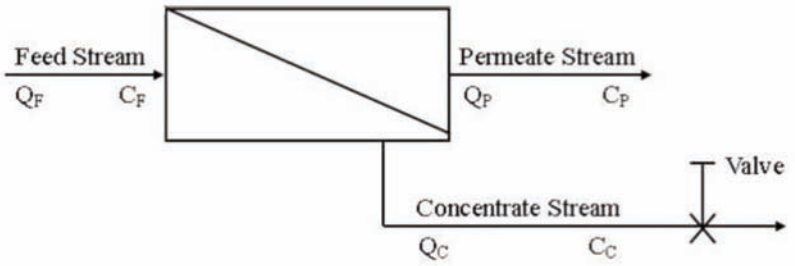
Figure 7 is a schematic of a complete membrane processing system (or a sin-

gle membrane element).

Note that the "feed" stream enters the system (or membrane element), and as the stream passes along and parallel to the surface of the membrane under pressure, a percentage of the water is forced through the membrane polymer producing the "permeate" stream. Contaminants are prevented from passing through the membrane based on the polymer characteristics. This contaminant-laden stream exits the membrane system (or element) as the "concentrate" stream, also known as the "brine" or "reject".

The permeate rate of a given membrane element cannot be changed without varying the applied pressure or temperature. Recovery, however, can be easily changed by varying the feed flow rate to the element, and this is one of the variables that is controlled by the system designer.

The effect of recovery on system performance is important. As recovery is increased, the flow rate of the concentrate stream diminishes; all contaminants that are rejected by the membrane and concentrated in the concentrate stream become more concentrated. This is illustrated in Table V and Figure 8.



Q_F - Feed Flow Rate
C_F - Solute Concentration in Feed
Q_P - Permeate Flow Rate
C_P - Solute Concentration in Permeate
Q_C - Concentrate Flow Rate
C_C - Solute Concentration in Concentrate

$$\text{Recovery} = \frac{Q_P}{Q_F}$$

(Expressed as Percent)

TDS = Total Dissolved Solids: Usually considered the total of the ionic contaminants (salts) in solution.

mg/L (milligrams per liter) is the same as ppm (parts per million)

Figure 7, Membrane System Schematic

One way to understand "concentration factor" is to think in terms of the

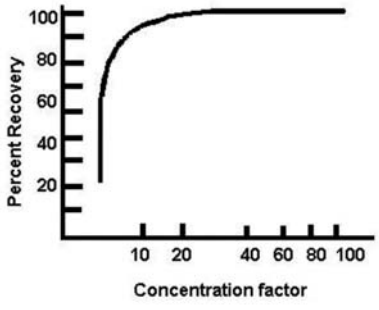


Figure 8, Effect of Recovery on Concentration Factor

evaporation or distillation process. If half of the given volume of water is distilled and the condensate recovered as pure water (permeate), this is the same concept as operating a membrane system at 50% recovery. Evaporation of three-fourths of the water is 75% recovery, and so on.

The advantages of operating systems at high recoveries are that the volume of concentrate is small and the flow rate of the feed pump is smaller. The potential disadvantages are significant:

Higher concentration of contaminants can result in precipitation and greater propensity for fouling.

In nanofiltration and reverse osmosis applications, the concentrated salts will result in higher osmotic pressure, requiring a higher pressure pump and a more pressure resistant system.

Also with RO and NF, as recovery is increased, the ionic purity of the permeate decreases.

As higher recoveries reduce the quantity of concentrate to be discharged, the higher concentration of this concentrate stream can itself present discharge problems.

The issue of recovery is definitely application specific: most water purification applications – those treating raw water to be purified for some downstream application (drinking, product manufacturing, rinsing, etc.), generally operate at relatively low recoveries, not exceeding 85%, even for the largest applications. In general, most water purification applications involve feed water conductivities that are relatively low; the one exception is seawater desalination. Usually the larger the system, the higher its recovery.

For wastewater treatment and water reuse applications, the minimum recovery is usually above 90%.

It is possible to completely close off the concentrate line, through the use of a valve, thereby, using the membrane as a conventional or "dead-end" filter, forcing 100% of the water through the membrane, with occasional periods when the concentrate valve is opened to allow the crossflow feature to reduce the concentration of contaminants at the surface of the membrane. Some membrane elements of tubular, capillary (hollow) fiber or plate and frame configuration can also be "backwashed," which involves running permeate (or another high quality water supply) backwards into the element to dislodge suspended materials from the surface of the membrane.

RECOVERED WATER USES

Obviously, with the flexibility provided by membrane technologies, and supplemented by such polishing processes as activated carbon adsorption, ion exchange, and others, it is possible to treat any contaminated water supply and reuse it for virtually any application. The concentrate streams resulting from membrane operations may also be used within an industrial facility for floor cleaning, cooling tower makeup, parts prewashing, etc. It's a matter of challenging the ingenuity of the process engineer.

CONCLUSION

Slowly but surely, the mindset of water recovery and reuse to fill the unmet needs associated with water quality issues, is reaching global proportions.

As indicated, there are treatment technologies available to meet the most daunting challenges, such as turning sewage into drinking water.

With competent testing and design engineering, coupled with determination and financial commitment, virtually any wastewater reuse application can be solved. FN

Physiochemical Examination of Membrane Fouling

By H. Alper, Andy Narayanan, Lance Rodeman, Matthew Goysich and Karthik Nagarajan

Fouling of reverse osmosis and other membrane filtration elements is becoming an urgent issue. This is due to the rapidly increasing demand for water re-use and recycling being generated by environmental concerns, the water demand of emerging alternate energy sources, and by the need for more economical and effective waste treatment and process water management. Although there has been a nebulous consciousness of the problem and its causes and effects, a definitive understanding and uniformly effective remedies remain elusive. This article examines some of the dynamics and the physical and chemical changes which occur on the membrane during this process.

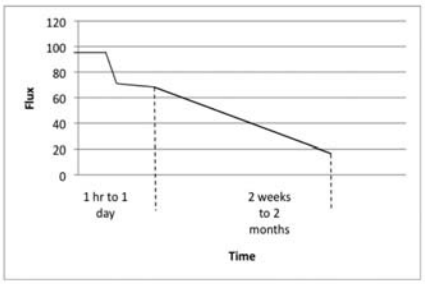


Illustration 1: Flux vs. Time

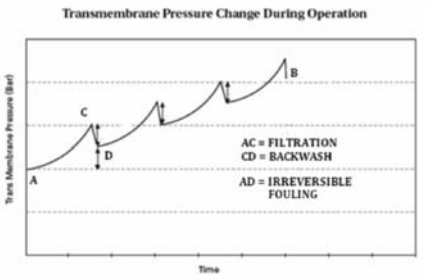


Illustration 2: Trans Membrane Pressure vs. Time. (Miller 2009)

DYNAMICS

Illustrations 1 and 2 are approximate graphic depictions of typical membrane behavior, which has been elucidated independently in numerous academic, military, and industrial works and publications.

Graph #1 illustrates that a rapid, significant decline in flux occurs on a clean membrane within hours of start-up followed by a more gradual decline in flux over a more prolonged period taking from 1 week to numerous weeks.

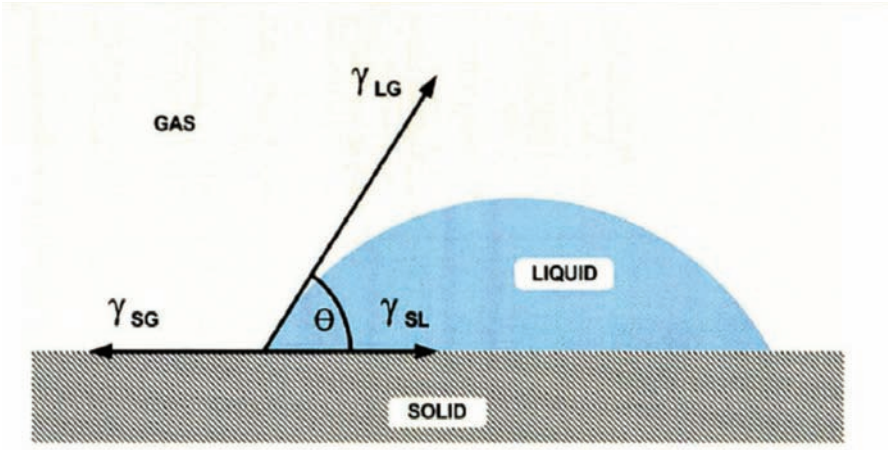


Fig. 1: Contact angle of a liquid droplet on a solid surface at the air-solid-liquid contact point.

Fig.2: Comparison of Contact Angle between clean and fouled membrane surface.

Component Surface Energy Data				
Sample	Overall Surface Energy (mJ/m^2)	Polar Comp. (mJ/m^2)	Dispersive Comp. (mJ/m^2)	Surface Polarity (%)
Fouled RO Surface	**54.87**	**8.75**	**46.12**	**15.94**
Clean RO Membrane	**45.07**	**2.22**	**42.85**	**4.93**

The initial decline in flux is too rapid and severe to be accounted for by build-up of foulant and indicates a change in the surface energy of the membrane and of the interfacial tension between the membrane and water. Once the surface of the membrane has been denatured in this way it is more susceptible to accumulation of organic, inorganic and biological material, which accounts for the period of gradual decline.

Graph #2 illustrates that trans membrane pressure increases with time and that back washing or cross flow is unable to return the membrane to its initial condition even after chemical cleaning. The slope from A to B is indicative of accumulation. The gap such as from A to D indicates irreversible alteration of surface energy and flow dynamics.

SURFACE ENERGY

To test the above hypothesis the surface energy and interfacial tension were compared on a clean and a fouled polysulfone membrane surface by measurement of contact angle of both fresh and salt water on the membrane.

Young's Equation

Young's Equation is given by:

$\gamma_{SG} = \gamma_{SL} + \gamma_{LG}\cos\theta$ as illustrated in Fig. 1 where γ_{SG} represents the solid-gas interfacial energy, γ_{LG} describes the liquid gas interfacial energy and γ_{SL} represents the solid-liquid interfacial energy. *(Gorcea & Laura, 2010).*

Fig. 2 shows that there is a drastic change in water droplet contact angle between a clean and a fouled membrane surface. The contact angle is indicative of the interfacial tension and can be used to calculate the interfacial surface energy.

Young's equation was used to calculate the overall surface energy and its components.

The results in the table below (Component Surface Energy Data) show that the total surface energy, the polar component of the surface energy, the dispersive component and the percentage surface polarity have in-

Fig. 3: R.O. membrane surface close up, removing solids from membrane surface.

creased. The surface has become much more polar and, therefore, hydrophilic. The overall surface energy can be considered to be the surface tension of a solid. Increase in surface energy indicates reduction of hydrophobicity meaning that the membrane is more easily penetrated by water. Since the basis of operation of an RO is employment of hydrophobic polymeric membrane, this drastic change will certainly alter the flow dynamics and efficiency of the membrane. The ability of water to penetrate the polymer also implies that water-soluble organics being carried in the water can be transported and deposited partially under the surface of the membrane. This would account for the inability of backwash, cross flow or even chemical cleaning to reverse the fouling once it has begun. Once the membrane has been altered in this way it is now much more susceptible to external build-up of organic and biological materials.

COMPOSITION OF FOULANTS

Foulant material was extracted with solvent and characterized by GC/MS.

The molecules, which were indentified, fall broadly into three kinds (See table Chemical Composition): organic compounds resulting from geologic oil forming processes (i.e. #5), organic compounds from living or decomposing microbes (i.e. #6, #7), and compounds of anthropogenic origin (i.e. #2).

The compounds of biological origin tend to be amphiphatic water miscible compounds with polar and non-polar moieties. These sorts of compounds will disperse in water until they encounter a non-polar interface such as polysulfone membrane. Upon contact with an oleophilic interface the molecule will exhibit surfactant like behavior with the non-polar tail embedding into the polymer (similar to an oily plasticizer) and the polar head of the molecule will protrude into the water phase. The result will be an increased surface polarity as was observed in the droplet tests. The membrane will become more permeable to water result-

Peak #	Time	Name	Formula
1	1.92	Molybdenum, [(1,2,3,3a,7a-)-2-methoxy-1H-inden-1-yl]bis(3-2-propenyl)-	C16H19MoO
2	2.18	Bis(benzimidazol-2-ylmethyl)sulfone	C16H14N4O2S
3	2.39	1,12-Dicarbadodecarborane, 2-benzimidazol-1-yl-	C9H16B10N2
4	2.69	2-Phospha-4-titanabicyclo[3.1.0]hex-2-ene, 3-t-butyl-6,6-dimethyl-4,4-di-(-5-cyclopentadienyl)-	C20H27PTi
5	2.98	Phenanthro[1,2-c][1,2,5]selenadiazole	C14H8N2Se
6	3.12	4,25-Secoobscurinervan-4-one, O-acetyl-22-ethyl-15,16-dimethoxy-, (22)-	C27H36N2O6
7	3.2	5,8,11,14-Eicosatetraynoic acid	C20H24O2
8	3.41	[1,1'-Bicyclopropyl]-2-octanoic acid, 2'-hexyl-, methyl ester	C21H38O2
9	3.6	1,12-Dicarbadodecarboran-2-amine, N-(4-clorophenyl)-	C8H16B10ClN
10	4.64	Silanamine, 1,1,1-trimethyl-N-[2-[(trimethylsilyl)oxy]-2-[4-[(trimethylsilyl)oxy]phenyl]ethyl]-	C17H35NO2Si3
11	5.27	1,1,2,2,3,3-Hexamethyltrigermane	C6H20Ge3
12	9.68	Acetic acid	C2H4O2
13	9.94	Silanediol, dimethyl-	C2H8O2Si
14	10.45	Butanoic acid	C4H8O2
15	11.63	Octanal	C8H16O
16	12.16	Limonene	C10H16
17	14	Nonanal	C9H18O
18	14.19	Molybdenum, [(1,2,3,4,5-)-1-(1,1-dimethylethyl)-2,4-cyclopentadien-1-yl]bis(3-2-propenyl)-	C15H23Mo
19	14.36	Silanediol, dimethyl-	C2H8O2Si
20	15.46	Benzeneethanamine, 2,5-difluoro- ,3,4-trihydroxy-N-methyl-	C9H11F2NO3
21	18.56	n-Decanoic acid	C10H20O2
22	18.97	2,4,7,9-Tetramethyl-5-decyn-4,7-diol	C14H26O2
23	20.34	Phenol, 2,4-bis(1,1-dimethylethyl)-	C14H22O
24	22.24	1-Nonadecene	C19H38

Table: Chemical Composition

ing in subsurface penetration of exopolysaccharides and above the surface accumulation of organic foulants, such as oil and grease.

DISCUSSION

The composition and behavior of water is much more complex than has been assumed for the past few decades as evidenced by Genomic sequencing of Ocean Water conducted as part of the Census of Marine Life project. Approximately 18 million different DNA sequences have been discovered suggesting the existence of millions of new species of unknown and for the most part unseen microbes. Many of these species are tiny and not seen by conventional microscopy. It is estimated that there are a billion microbial cells in every liter of what would be considered clean sea water. The components of these cells have been referred to as SMP's (Soluble Microbial Products), EPS (Extracellular Polysaccharides), Exopolysaccharides, Endotoxins and a number of other terms. These compounds are produced due to decomposition of dead cells and have functions in the living cell related to cell adhesion and defense from the environment when stressed. Interestingly, the cleaner the water gets the more stressed the remaining microbes become resulting in production of more exopolysaccharides. This mechanism can probably account for some of the anomalous fouling phenomenon even when "cleaned" water is used in a membrane system.

The data in this paper suggests a two-stage fouling process. In the first stage membrane surface energy and flow dynamics is altered by as little as a monomolecular layer of exopolysaccharide.. The surface energy is a surface active phenomenon and so in the range of micrograms/sq. ft is enough to cause this effect. Once the surface is thus altered other organic foulants are able to penetrate and accumulate on the membrane eventually causing catastrophic pressure build up. Considering the ubiquitous nature and tiny amounts of EPS required, a two-stage approach must be taken to prevent or inhibit fouling. Technology currently exists for removing trace amounts of organic foulants so as to eliminate or reduce the secondary gradual organic build-up stage. This technology should be used even if organic analysis indicates less than 1 ppm oil and grease. In a system, which processes 10 million pounds of water per day - even 100 ppb is equivalent to 1 lb. of oil and grease per day - more than enough to build up on elements. Elimination of the surface energy altering exopolysaccharides is trickier due to their amphiphatic nature. We are currently conducting research to investigate the potential deactivation of these compounds through the use of bioactive cations.

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Capaceon Filtration Media from Hollingsworth & Vose Sets a New Standard for Media Performance

By Andrew Shepard and Doug Guimond, Hollingsworth & Vose Company

Engineers are often asked to fit ten pounds of stuff into a five pound bag. Lately, the combination of market forces, driven by new emission standards, cost reductions and space constraints have created a challenge for filter designers: how to put increasingly higher levels of performance into smaller and smaller spaces at lower and lower costs.

Capaceon®, a new technology from Hollingsworth & Vose, helps make this feat possible by breaking the traditional link between filter media basis weight and filter life. Equally beneficial for air, lube and fuel applications, Capaceon was designed to enhance performance in tighter spaces. With Capaceon, H&V can tailor the distribution of media pores, resulting in significantly increased dust holding capacity. Capaceon's robust media structure reduces process engineer rework by running on existing filter element production assets in the same manner as standard cellulose products today.

Designers are split on how to best leverage Capaceon's benefits. The need to extend the performance of filter media is growing to support many diverse industry demands:

- Higher fluid cleanliness requirements
- Longer service intervals
- Smaller filters
- Reduced operating costs
- Lower total cost of ownership

Some Capaceon premium filters are designed to achieve much longer filter life while also improving efficiency, lowering pressure drop and improving energy savings throughout the lifetime of the element. Alterna-

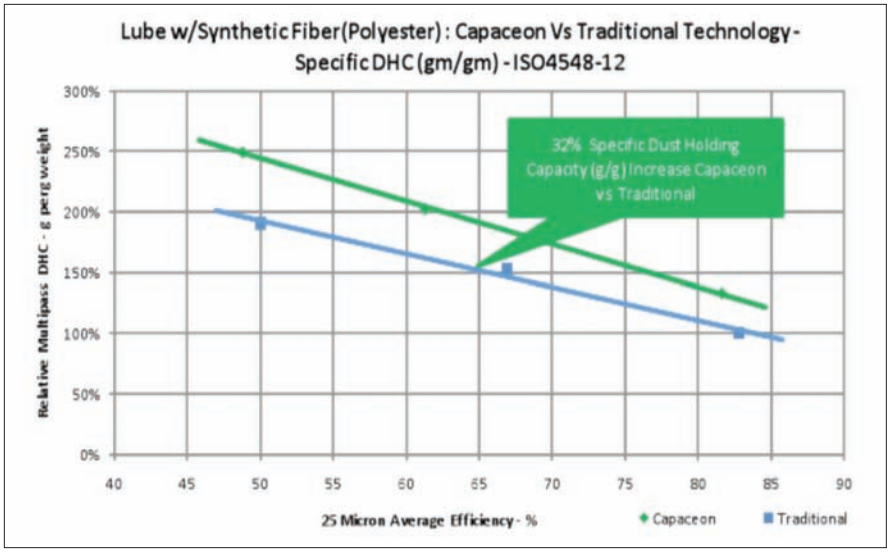


Figure 1 – Capaceon & Traditional Lube Filter Media w/ synthetic - Specific DHC, g/g, vs. Efficiency.

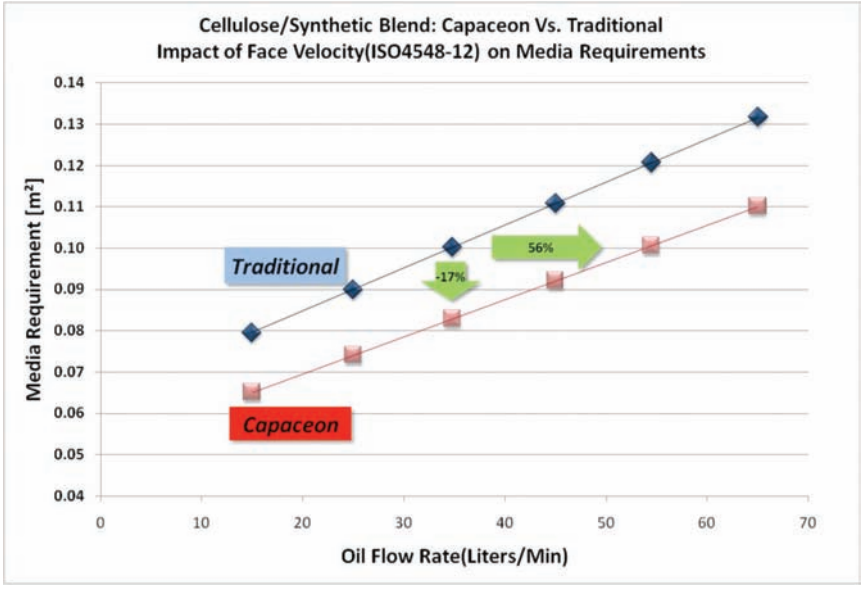


Figure 2 – Constant Filter Capacity (15.4g). Capaceon Media w/ synthetic – Impact of Face Velocity on filter element media requirements.

tively, some Capaceon cost-reduction designs maintain current element lifetime and performance while reducing the required surface area and total cost – a change that typically reduces performance in other media due to lower void volume and higher face velocities. To best meet these diverse market requirements, a filter media needs to operate across a wide range of element sizes and designs, cope with a wide range of flow rates and meet the demands for improved filtration efficiency and filter life. Working with filter designers, Capaceon media can accommodate all of that and more.

THE CAPACEON DIFFERENCE

Capaceon is a new fibrous filter media technology that results in dramatically improved dust holding capability versus traditional fibrous filter media. Typical fibrous filter media is produced using a "wet-laid" forming process, wherein different specialty fiber types are combined and suspended in a liquid bath and then dried and impregnated with resin to form the end product. The types of fibers chosen generally dictate the physical properties of the filter media produced. Specialty fibers, resin chemistry, and process variables all play a critical role in differentiating the end products.

The filtration performance of traditional fibrous filter media is largely influenced by its basis weight, overall density, and the pore size gradient. While basis weight and density directly translate to more media and/or pores to capture more particles, the pore size structure dictates if the filter can efficiently use all of the media that is available. Filter media structure typically has a natural gradient from tight pore structures first forming adjacent to the wet forming wire (wire side) and a more open pore structure on the top of the sheet (felt side). This gradient density is typically controlled using the manufacturing process variables. Poor gradients or a poor match of gradient design to the application can result in wasted pockets of unused media blinded off by filled adjacent pores.

Although it is produced using many of the same traditional fibers and wet-laid forming processes, the use of the Capaceon technology changes the dynamics by which the pore structure is formed and controlled through the depth of the filter media. This allows the filter not to waste any of the available media performance. This new technology is equally applicable for Air, Lube Oil, and Fuel filter applications. To illustrate how Capaceon can effectively be used within different segments of the marketplace, let's take a look at three hypothetical but typical designers trying to meet complex new market needs.

Design Engineer Bruce - Increase Lube Filter Lifetime Quickly and Easily

Bruce needed to improve his lube filter lifetime without sacrificing efficiency performance while reducing

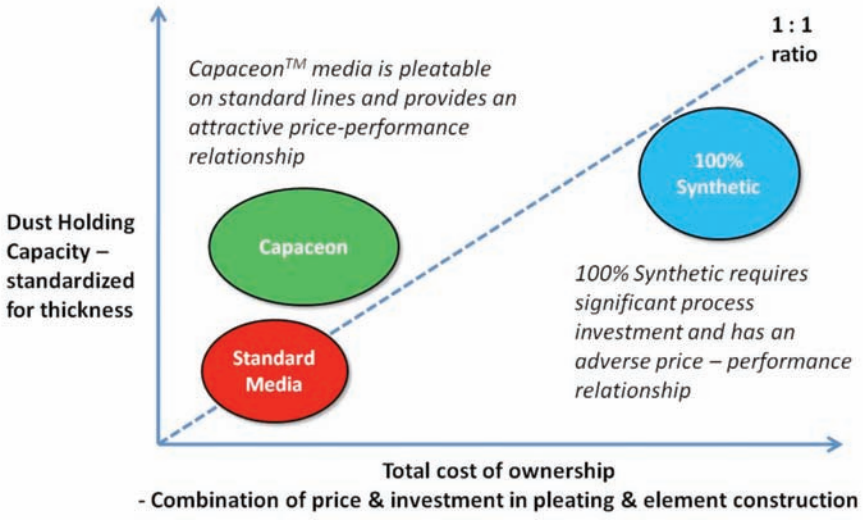
size. In the prior years, the lube oil suppliers had improved their additive packages, creating better oils, which allowed the OEM to recommend a longer service interval. This had created the need for a longer-life lube oil filter capable of removing contaminants caused by oxidation or nitration during these extended service periods. In addition, this long-life lube filter had to be resistant to the formation of acids in the system over time and contain a high level of synthetic fiber such as polyester to maintain structural integrity under harsh conditions. Bruce was looking for the easiest and most cost effective way to make the improvement. If possible, he wanted to stay with traditional fibrous filter media for cost and processing benefits and not move to more expensive fiber options. Increasing media area seemed to be the most obvious solution before looking into Capaceon.

At the targeted 50% efficiency at 25 microns, Capaceon media provided a 32% increase in DHC with the same weight and surface area as the existing traditional media. Bruce was able to use the exact same filter design and pleat pattern with no changes to the pleating or assembly process. Just by changing the media, the new filter met the improved capacity market requirements without sacrificing other performance. While Bruce had anticipated having to make time-consuming filter design and process changes, this rework was, for the most part, completely avoided by changing the media to Capaceon.

Design Engineer Linda – Reduce Lube Filter Costs, Shrink a Lube Filter to Fit a New Application

Linda needed to shrink an existing lube filter design. Previous size reduction actions had focused on higher capacity synthetics which ultimately resulted in higher cost and production issues Linda did not wish to repeat. The current consensus recommendation had been to try to squeeze the cartridge height and add pleat height.

Instead, Linda worked with Capaceon media to reduce the size and number of pleats in their long-life lube elements. The two initial concerns with reducing media area - impact of higher face velocity on efficiency and overall capture capacity - proved baseless. Testing showed no significant degradation of relative efficiency of the Capaceon media as face velocity changed. Based on the media tests, the element designer investigated three design options with three different value propositions. First option was to maintain the same media area and increase element lifetime by 32% with Capaceon. The second option was to tailor this same media area to offer an over 50% higher flow that retained the same capacity. In this case study, the designer reduced element media usage by 17% in order to maintain equivalent element life and performance while reducing size. The existing 0.1 m^2 filter element had 15.4 grams of capacity using traditional media at a typical 35 liters/min flow (0.58 cm/sec face velocity). Controlling



for constant filter capacity and oil flow requirements, the designer reduced the media area by 17%. The new filter design only required 0.083 m² of media – a 17% media reduction – to achieve the same filter capacity. Ancillary cost benefits resulting from a smaller package – enclosure materials and processing – also fell to the bottom line.

Design Engineer Steve – Reduce Diesel Fuel Filter Complaints

Steve needed to increase the capacity and operating lifetime of his fuel filter design. In Steve's world, emission regulations, new bio-diesel blends, and fuel component requirements were all impacting the engine design and therefore the fuel filter requirements. Previous market requirements for greater particulate efficiency and water separation had driven finer and more restrictive media. While cleaner fuel passed out of the filter, the higher efficiency and limited void volume also reduced filter life. New fuel blend changes also complicated the lifetime of existing filters. Steve needed help finding a cost-effective solution.

While Capaceon is not the whole solution to the complexities of new fuel filter requirements, it is playing its part. Many fuel filters are composites of multiple layers. Using the same principles as described above, the Capaceon processes are able to impact some of these layers to tailor pore density, reduce clogging, and increase overall filter lifetime.

Hollingsworth & Vose has plans to release a paper later in 2011 discussing how Capaceon will impact future fuel filter media.

IMPACT OF CAPACEON MEDIA

The key for future media designs lies in providing design flexibility for the filter element designer. The challenges of smaller elements with higher face velocities or fewer pleats are growing. While finer fibers and synthetic composites have their place, their impact on processing and material costs often make these approaches undesirable.

Regardless of the application – Air, Lube or Fuel - Capaceon offers designers increased flexibility and significantly greater life-time value for the money than either Traditional media or Synthetic media, such as:

- Ability to quickly design smaller, more durable elements to fit the needs of new future vehicles.
- Higher performance for a given standard element size and production set up.
- Ability to reduce the number of pleats and surface area in an element without a reduction in performance - saving space and reducing ancillary costs such as metal, plastic, and gluing costs.

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The Advantages of PTFE in Demanding Filtration Applications

By Randy E. Pepper, Ph.D., Plastomer Technologies

In today's highly competitive, global marketplace, companies are moving into higher value-added chemicals and materials. Further, environmental regulations are becoming ever more stringent as governments at the national, state and local levels are requiring that industries reduce waste and emissions. Thus, new technologies for capturing those wastes and emissions continue to evolve. In this competitive environment, the filtration design engineer or filter end user will require materials with increasing performance and durability. This shows that polytetrafluoroethylene (PTFE) is well suited to meet many of these demands and help the industry to meet its customer and environmental obligations.

PTFE OVERVIEW

PTFE was discovered by Dr. Roy Plunkett at DuPont in 1938. Its use was limited to wartime applications until after World War II, when it was first introduced under the trademark Teflon®. Today, there are many other suppliers for this material with annual worldwide usage in the range of 60,000 tons/year [1]. The unique properties of PTFE accrue from its structure shown in Figure 1 [2], where the large fluorine atoms form a sheath around the carbon backbone, protecting it from attack by any organic, acid, or base solvent, except at elevated temperatures. This sheath also imparts a low surface energy, resulting in a very low coefficient of friction (< 0.1) and nonstick properties [3]. Finally, this low surface energy renders PTFE both hydrophobic and oleophobic, so neither aqueous nor oily materials adhere to it. Thus, it is easy to mechanically remove any dust or filter cake which builds up on its surface.

PTFE is insoluble in all solvents below 300°C and has a useful property range from -260°C to +260°C. It is inert to UV radiation and has a V-0 flamma-

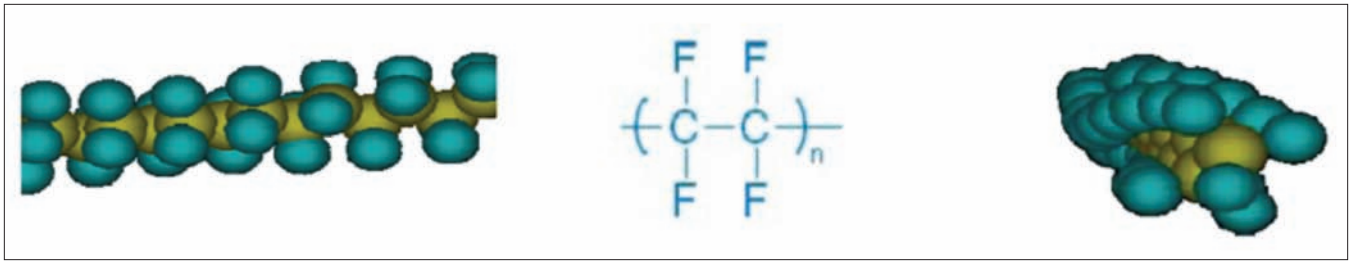

Figure 1. 3-D representation of the PTFE Molecule.

Table I – Chemical Resistance Overview for Selected Engineering Plastics [5]

			Acid				Aromatic	
Polymer:	Abbreviation	Ketones	Dilute	Conc.	Alkali	Alcohol	Hydro-carbons	Grease & Oil
Poly(ethylene terephthalate)	PET	- -	G	P	G	F	G	G
Polyamide-6, PA-66	Nylon	P	P	G	G	G	G	G
Poly(phenylene sulphide)	PPS	G	F	G	G	G	G	G
Poly(ether-ether-ketone)	PEEK	G	F	G	G	G	G	G
Polytetrafluoro-ethylene	PTFE	G	G	G	G	G	G	G
Nomex (aromatic polyamide)	Nomex	- -	F	F/G	G	G	G	G

P = Poor; F = Fair; G = Good

Table II – Continuous Use Temperatures of Selected Engineering Polymers:

	Maximum Continuous
Polymer	Use Temp.°C
Polypropylene (PP)	100[1] - 130[2]
PET	115[2]
Nylon-6, Nylon-66	80[1] - 100[2]
PPS	220[2]
PEEK	250[2]
PTFE	260[3]
Nomex	370[4]

[1][6] [2][7] [3][8] [4][9]

bility rating, which recognizes its extremely high Limited Oxygen Index of 95%, which exceeds that of any other polymer [4].

Table 1, extracted from reference 5, compares the chemical resistance of PTFE vs. other common engineering polymers used in fiber form. It is seen that PTFE is the only polymer showing a "Good" rating all the way across.

Table II presents the heat resistance of PTFE and other engineering polymers as a function of their "continuous use temperature," which is the maximum temperature that they can withstand under zero load. This is a relative measure of how a polymer will perform at higher temperatures. Here one can see that PTFE has excellent heat resistance, which should make it suitable for many hot stack gas applications, and especially those with acid or base concentrations in the flue gas.

While PTFE is semicrystalline, melting in the range of 320°C–345°C (depending upon its heat history), it cannot be melt processed, as it begins to decompose prior to melting. Thus, PTFE is processed into film and fiber form primarily using two processes. In the first, the PTFE fine powder is combined with cellulosic binders in an aqueous mixture that is pressured through fine holes into a hot gas atmosphere, which drives off the water. The fiber is then sintered to consolidate its structure and drive off the cellulosic binders [10]. This method allows for production of multifilament yarns and staple fibers similar to what are obtained from melt processable polymers.

In a second process, the PTFE reactor powder is combined with a lubricating oil to form a paste that is solid-phase extruded through a film die at temperatures near room temperature. The film is calendered, then subsequently stretched, either biaxially (i.e., stretched in both the machine direction and perpendicular to the machine direction) or uniaxially (machine direction only) to form an "expanded" film or "membrane." These expanded PTFE (or ePTFE) films are quite strong and have a pore size which can be engineered to pass vapors and gases, while blocking water droplets (first patented by W. L. Gore in the early '70's [11] and marketed as "Gore-Tex"). Much ePTFE membrane is used in the filtration industry.

Another useful form of ePTFE is produced by highly orienting the extruded film in one direction, then slitting it into monofilaments between 400 and 1,200+ denier (where denier is the weight of a 9,000 m length of the fiber in grams). Figure 2 shows a cone of

PTFE slit monofilament.

These monofilaments are more easily used, especially for sewing, when they are twisted into threads as shown in Figure 3.

PTFE monofilament or thread is suitable for filter manufacture either as:

1) A sewing thread for sewing filter bags of PTFE or other high performance fibers used in hot gas filtration, e.g., bag house filters located in the stacks of coal-fired boilers, cement plants, etc.

2) As a woven scrim for needle punching PTFE or other high-performance fibers to form the fabrics used in bag house or other filter formats.

3) A filament for wound-core filters for corrosive liquid filtration applications.

All of these applications exploit the superior chemical resistance and excellent heat resistance of PTFE.

Figure 4 presents the relative cost of

Figure 2. PTFE Slit Film Monofilament – Black pigmented and White unpigmented.

Figure 3. PTFE thread twisted from slit film monofilament – Black pigmented and White unpigmented.

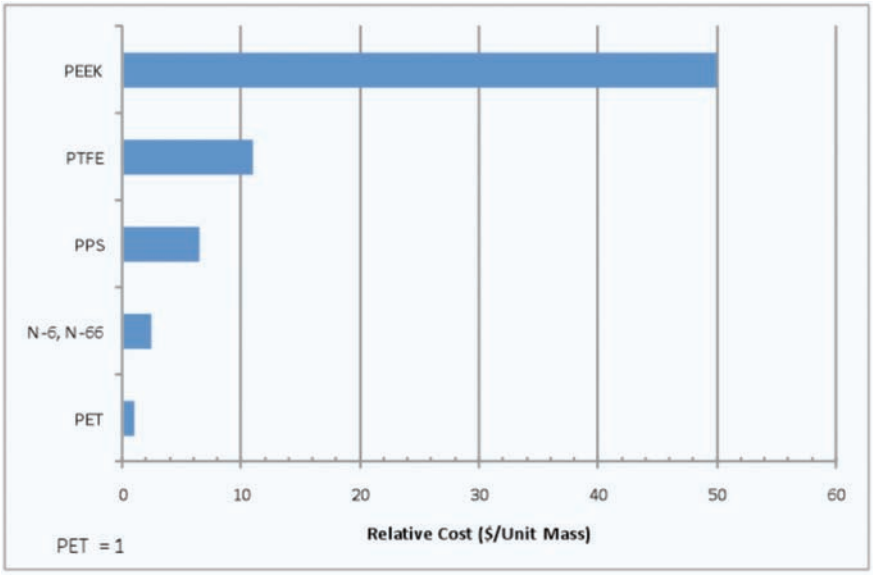

Figure 4. Relative Cost of PTFE vs. Selected Engineering Plastics. [1]

PTFE vs. some other common engineering plastics, derived from cost/unit volumes reported in Reference 1[1], with PET's cost/unit mass defined as 1.0. As the figure shows, the higher cost of PTFE vs. other more common engineering plastics restricts its application to those end uses where its low coefficient of friction, high UV resistance, excellent biocompatibility, unsurpassed chemical resistance and high heat and flame resistance provide a competitive advantage.

For ePTFE, the room temperature creep resistance of PTFE can be an issue in part because of its excellent ductility at cryogenic temperatures. Creep resistance can be improved somewhat with comonomer addition, the so-called modified PTFE resins. With sintered PTFE, fillers can be added which substantially reduce the creep resistance, but these fillers may compromise COF or chemical resistance, while greatly reducing drawability. Finally, despite its low COF, PTFE tends to demonstrate lower abrasion resistance relative to what is seen with a PET or Nylon, although these cannot tolerate the same severity of chemical and temperature environments.

CONCLUSION

PTFE has been in the market for more than sixty years, but it is still finding new applications at the frontiers of the chemical and combustion industries, where its unique mix of very low and high service temperatures, chemical resistance, and low coefficient of friction should make it one of the first materials to be considered in any air or liquid filter application. FN

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[1] The following densities (g/cm3) were used to convert from cost/unit volume [1] to cost/unit weight: PET - 1.37, Nylon-6,66 - 1.14, PPS - 1.35, PTFE - 2.2, and PEEK - 1.32. Relative PEEK price in Ref. 1 adjusted to bring current.

Not All HEPA Filtration Systems Are Created Equal: 5 Tips for Selecting the Right Filter

When planning a new cleanroom or maintaining an existing one, the choice of filters can be critical to product quality, production yields and regulatory compliances

The key to achieving contamination control, whether in the hospital operating room or the semiconductor assembly area, is the air filtration system, which is ultimately dependent on the reliable performance of HEPA (and in some cases ULPA) filters. This includes cleanrooms and mini clean filtration "environments" such as biosafety cabinets, clean benches and fume hoods.

While most HEPA filters may look the same, they vary widely in quality and high-purity performance. These filters also vary in design, pressure resistance, frame construction, sealant, and temperature capabilities.

Although cleanroom filtration systems are certified to meet initial contamination containment capabilities and regulatory requirements, the effective lifespan of filters may be limited, requiring premature replacement to avoid costly air quality problems – that is, if the user is aware of the problem. Examples of limiting factors include filter design shortcomings, marginal quality of filter material, incomplete or inappropriate filter testing, and insufficient heat resistance in high-temperature applications.

"Inadequate filtration in cleanrooms or clean spaces can result in lower production yields and unsatisfactory conditions," said Wayne Copeland, president of CEPA Operations, Inc. (Ontario, CA) a cleanroom certification service and HEPA filter specialist. "It can also mean failure reports, downtime and frequent replacement or maintenance – all of which can get very expensive."

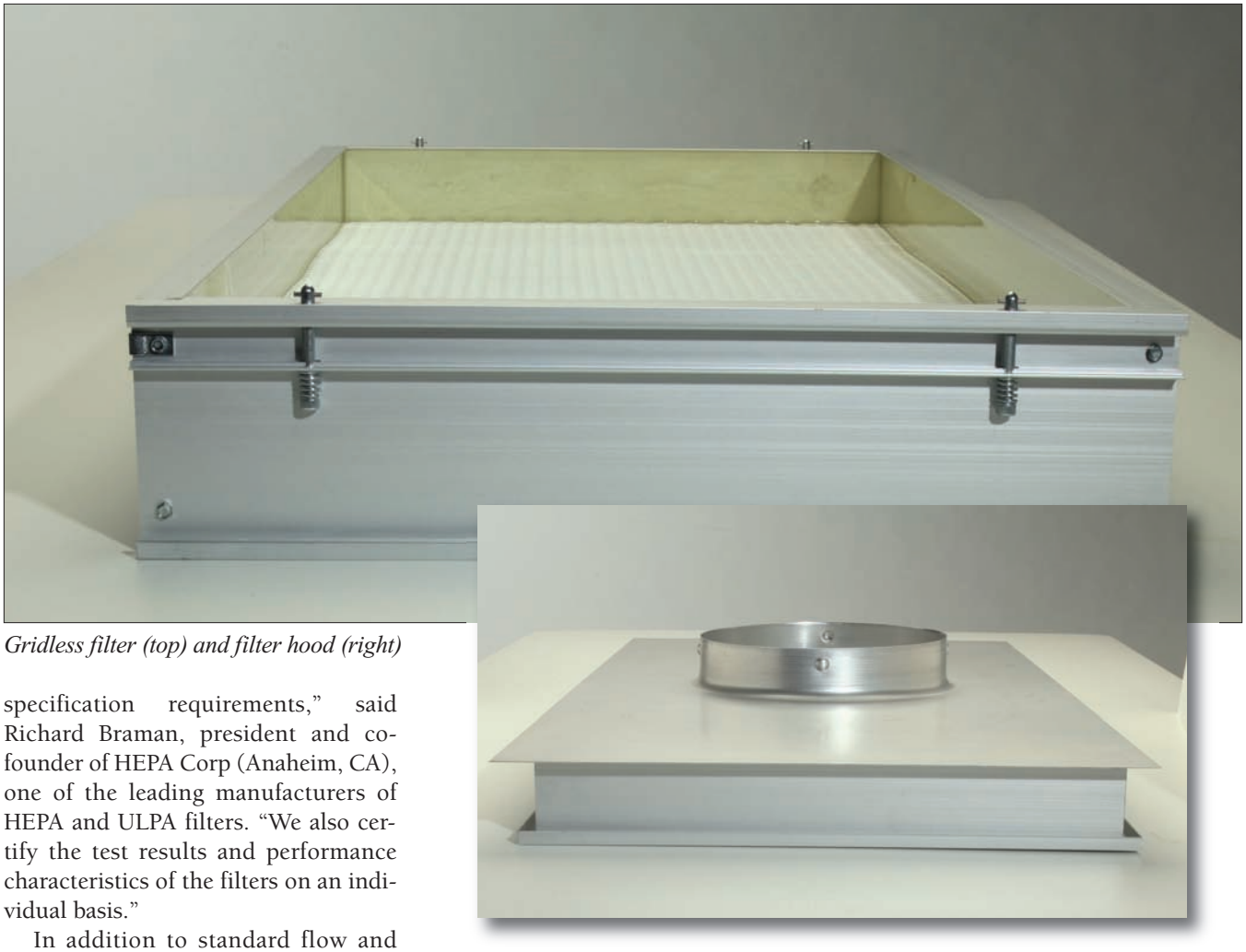
Bio-safe/clean room filter installed in ceiling.

Given the pivotal impact HEPA filters have on cleanrooms and other clean environments, here are five points that experts say should be considered before replacing current filters or specifying a new cleanroom system:

TEST ACCORDING TO APPLICATION

Prior to purchasing any HEPA filters, Mr. Copeland advises his customers to confirm that all HEPA (or ULPA) filters are tested individually, because batch testing is unacceptable.

"We have a strict policy of individually testing every customer's filter according to the application and



Gridless filter (top) and filter hood (right)

specification requirements," said Richard Braman, president and co-founder of HEPA Corp (Anaheim, CA), one of the leading manufacturers of HEPA and ULPA filters. "We also certify the test results and performance characteristics of the filters on an individual basis."

In addition to standard flow and pressure testing, some industries require leak testing. However, the standard oil-based aerosol DOP (dioctyl phthalate) leak testing is not permitted in some sectors, such as optics and semiconductors. For those ultra-sensitive applications Mr. Braman said his firm uses PSL (polystyrene latex spheres) for leak testing.

USE DEEP PLEATS TO SAVE ENERGY

The lower a filter's resistance to air flow, the less air handler force is required to push the required amount of air through a filter. Hence, the less energy expended to move the required air via electric fan. Mr. Copeland said the best way to lower resistance is with deep-pleated HEPA filters, which are designed to give more surface area and thus dramatically improve filter efficiency.

"We have used HEPA Corp's deep-pleated filter packs that more than doubled the filter media size, and the energy savings were very substantial," said Mr. Copeland. "The original filter installation had a resistance in the .6"-.7" Water Column (in inches) range. By installing the deep-pleated filters we reduced the pressure to the .3" W.C. range, which allowed the customer to slow their air handlers by 50 percent and also shut down a cooling tower. While the initial investment was higher than standard filters, the savings in electric power consumption may have saved that amount within the first year. Plus, they won't have to change the filters for years to come, which will save substantial labor and material cost savings."

On the "green" side of the picture, because deep-pleated HEPA filters promise a substantially longer lifespan, that means improved sustainability and fewer products that end up in landfills.

ROOMSIDE SYSTEMS ARE EASIEST

Mr. Copeland points out that the difficulty of changing cleanroom filters is often overlooked by cleanroom designers and engineers. However, when replacement service is required, the cost includes much more than just the filters.

"When it is time to change the HEPA filters, the true cost includes downtime, labor and cleanup," Mr. Copeland said. "And those costs can really add up."

Mr. Copeland added that when changing out most individual terminal type filters, which can be time-

consuming because they are commonly a difficult replacement, a cleanroom can be tied up for an extended period of time. This will be very expensive in terms of production downtime. It also is a dirty operation, causing contaminants to enter the clean space, and that will require time and labor to clean properly.

To solve this situation Mr. Copeland recommends a "roomside replaceable" filtration system, such as HEPA Corp's Perma-Hood® filter system or Q3-4000® Gridless® ceiling filter system. Through the use of an innovative, patented latching system, filters and lights are suspended in a "gridless" double channel system. The ceiling is constructed and installed completely from the roomside. Filters are self-aligning; there is no need to lift the filters up into the plenum before putting in place, nor time-consuming squaring of a T-bar grid.

He said that with these gridless and modular systems he can change filters from 5-10 times faster than individual panels. "Plus, with a roomside replaceable you have a housing that stays permanently installed," explained Mr. Copeland. "So now you simply flip a couple of levers to change the filter out, so you have a much faster change with far fewer contaminants to deal with."

Mr. Copeland added that well-designed roomside filtration systems can improve the laminar flow of air in a cleanroom, making it easier to provide cleanest "first" air to desired areas within the room.

SOURCING CUSTOM AND ODD SIZES

For one reason or another, some cleanrooms and many mini clean environments (biosafety cabinets, clean benches and fume hoods) require custom, odd-size HEPA filters.

Many distributors don't stock odd-size filters simply because there are so many shapes and sizes, and orders may be difficult to predict. Some manufacturers evidently find odd sizes difficult to deal with, so they wait for like-size orders to accumulate before making the filters, which can cause extensive delays in turnaround time.

"Custom or odd sizes are a fact of life that we have to deal with," said Mr. Copeland. "Our company avoids the backlog that results from filter manufacturers who simply add these special size orders together until they have what they consider a sufficient number to run. In combination with required testing, those orders can take months to fill."

Mr. Copeland said one reason his firm sources from HEPA Corporation is that it is the only HEPA filter manufacturer he knows who will make filters to custom specifications and test them as part of the normal production flow. This means that custom shapes and sizes will be tailor-made and delivered in weeks rather than months.

SPEC'ING HIGH-TEMPERATURE FILTERS

In the case of high-temperature applications, HEPA filters need to have special materials for the frames and seals, allowing them to handle temperatures of up to 750 degrees (F), and are available with a choice of frames and seals.

Applications that are performed in high-temperature environments require corresponding high-temperature ASHRAE, HEPA, or ULPA filters. However, it is essential to specify high-temperature filters according to appropriate filter media, frame and sealant capabilities. For example, while filters are readily available in various temperature ranges up to 750 degrees (F), the sealant method will determine the range, with urethane sealing appropriate for temperatures up to 230 degrees (F), and glass pack required for the highest temperature range.

Some consideration must be given to filter binders, also. Since the acrylic binder used in temperature ranges above 500 degrees (F) will burn off and produce smoke, products should not be introduced to the high-temperature environment until the smoke is exhausted.

Nevertheless, the variables governing the correct choice of high-temperature filters suggest that users confirm their choices. "Whenever in doubt about any filter specification, it's a good idea to talk to a filter manufacturer," Mr. Braman advised.

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Criteria for Selection of Pore Structure Characterization Techniques for Filtration Media

Dr. Akshaya Jena and Dr. Krishna Gupta, Porous Materials, Inc., Ithaca, New York, USA

The technique selected out of the many available should measure through pore throat diameter, distribution, permeability and volume while the filtration media are stable. Table 1 summarizes the strengths and limitations of the techniques (Figure 1) [1].

EXAMPLES OF SELECTION

Complete filter cartridges can be tested in complete filter cartridge tester which overcomes problems due to high flow, high correction factor, and variable cartridge size (Figure 2).

For accurate, reproducible and objective results obtained under controlled experimental conditions, the automated Advanced Capillary Flow Porometers is used (Figure 3). Tests can be performed under a range of application environments like compressive stress, temperature, and humidity.

Nano-Pore filter media - unstable under high - pressures can be tested by LLP. LLP uses an order of magnitude less test pressure and can measure pores down to about 3 nm (Figure 4).

For cost effective quick tests for routine production and quality control applications, simple porometer is used. The equipment is inexpensive, robust and very simple.

Pore structure of delicate nano-pore membranes is measurable by CCFP (Figure 5).

Cake filtration can be analyzed by cake forming porometer. It measures pore structure of media, creates cake on the media in the sample chamber, and measures the pore structure of the media containing the cake.

Pore volume, distribution, diameter and liquid permeability of media can be measured by LEP (Figure 6).

Table 1 Strengths and limitations of techniques

Techniques:	Capillary Flow Porometry	Nano-Pore Porometry	Liquid-Liquid Porometry	Capillary Flow Condensation Flow Porometry	Liquid Extrusion Porosimetry
Throat diameters:					
Nanometers	√	√	√	√	
500 - 0.013µm	√				
Largest	√	√			
Pore diameter:2000-0.05µm					√
Mean pore diameter	√	√	√	√	√
Pore Distribution	√	√	√	√	√
Gas permeability	√	√		√	
Liquid Permeability	√		√		√
Surface Area	√				
Pore volume					√
Test pressure	Moderate	High	Low	~ Zero	Low
Sample		Strong			Smooth surface

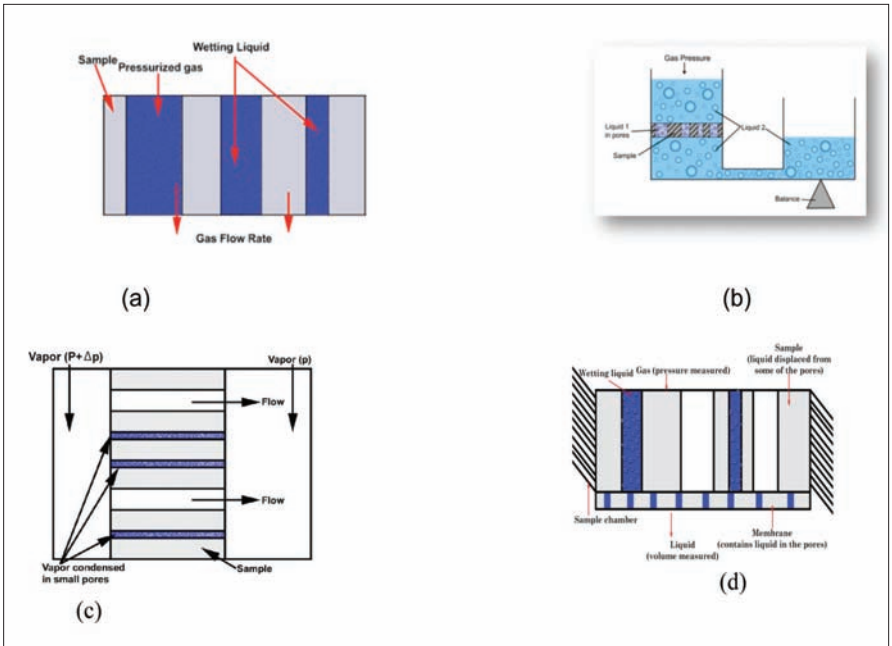

Figure 1. Principles of (a) CFP and NPP, (b) LLP, (c) CCFP , and (d) LEP

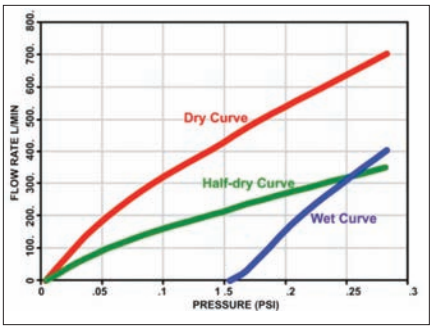

Figure 2. Data on cartridge

Figure 3. Advanced CFP

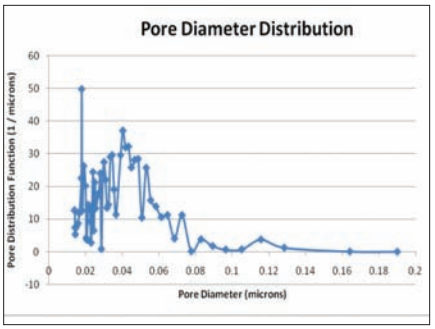

Figure 4.LLP pore distribution

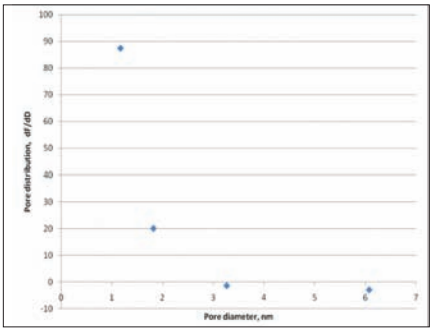

Figure 5. CCFP pore distribution

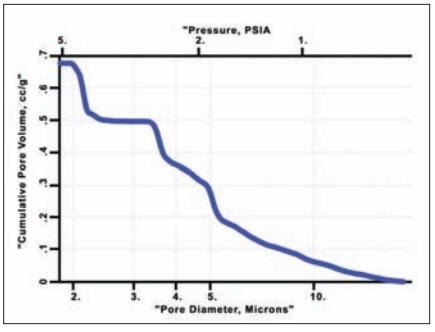

Figure 6. Depth filtration media

CONCLUSION

Selection of suitable pore structure characterization technique is essential to measure relevant pore structure of desired media.

Reference

Akshaya Jena and Krishna Gupta, Chem. Eng. Technol. 2010, 33, No. 8, 1241-1250.

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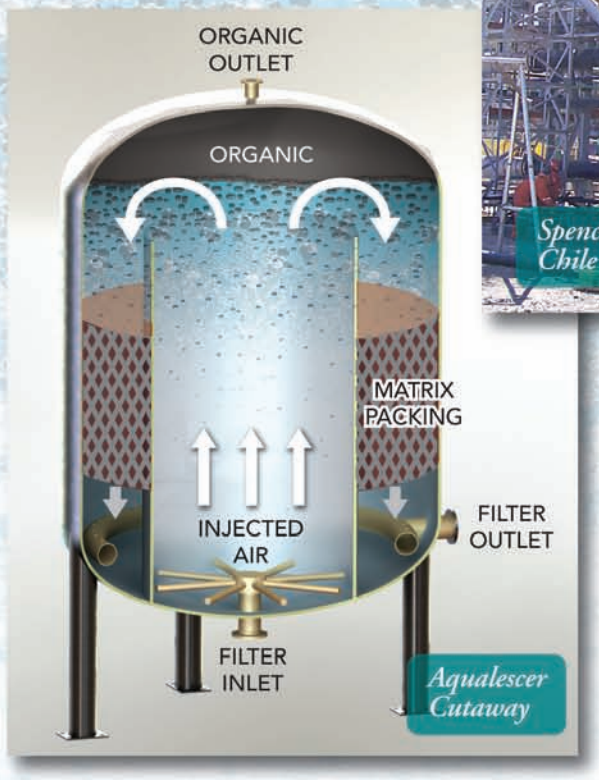

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