INDUSTRIAL STRENGTH MEMBRANE FILTRATION

V✧SEP® vibrating membrane system proves membranes aren't just for water anymore

by Greg Johnson and Brad Culkin, PhD

Many would argue that the most fundamental aspects of chemical processing are separation processes. In fact, the cost of operating separation processes can account for as much as 80% of total processing costs, especially for commodity chemicals. In an effort to increase productivity and reduce operating costs, engineers are now turning to membranes for their separation needs.

Utilization of polymeric membranes is becoming widespread and offers new possibilities for separation techniques in chemical processing, some of which were previously unimaginable. In addition to enabling new very fine selective separations, use of membrane filtration results in reduced capital, operating, and energy consumption costs. The potential for economic benefit to the user is truly revolutionary.

Conventional separation technologies are complex but essential to chemical processing and the profit derived from it. Many common products are processed using materials or chemicals that are purified with separation technologies such as distillation, evaporation, centrifugation, clarification, or precipitation and flocculation techniques. The quality of these separations directly affects product purity and customer satisfaction.

Now chemical processing manufacturers facing global competition are looking for new manufacturing technologies that can improve product performance, reduce operating costs, and prevent pollution problems before they occur. Conventional separation processes have been around for many years and have been optimized to the greatest extent possible. With new regulations on emissions, demand for higher product quality, and escalating energy costs, traditional separation methods cannot achieve the purity or efficiency levels required for today's market. Innovative separation technologies are needed for this changing environment. To be commercially viable, the new technologies must offer significant cost savings and product quality improvements.

Polymeric membranes have continually evolved from their initial use as water purification and laboratory devices. Thousands of patents have been filed in recent years having to do with the polymer chemistry of membranes or the method of utilizing the membranes. Through the innovations in membrane chemistry and design, membrane filtration technologies will soon establish a leadership role in the rapidly growing specialty chemical market. Novel membranes such as Teflon®, Kynar®, and inorganic varieties have made it possible to filter in even the most aggressive chemical environments.

New chemical products or industries will be created by innovative chemical processing companies with the help of new selective membranes. Membranes are available in many sizes ranging from the tightest (Reverse Osmosis) to the most open (Micro-filtration) and are made using dozens of various polymers and backing substrates. A membrane system can be designed to perform advanced separations including those that are physically and chemically difficult to achieve. In addition, membranes can change the product quality or cost of production for some chemical products that were previously considered uneconomical.

New Logic develops VSEP for chemical processing separations

Historically, membrane manufacturers have utilized tangential or crossflow filtration to reduce solids loading or fouling of the membrane. In this method, the feed material is pumped at high velocity into the system, which creates shear forces at the surface of the membrane. However, the forces were economically limited to between 10,000 and 15,000 s^{-1}. This has restricted crossflow type filtration to low viscosity, watery materials. In addition, a stagnant boundary layer remained on the surface, in which solids could accumulate and eventually impede the flow.

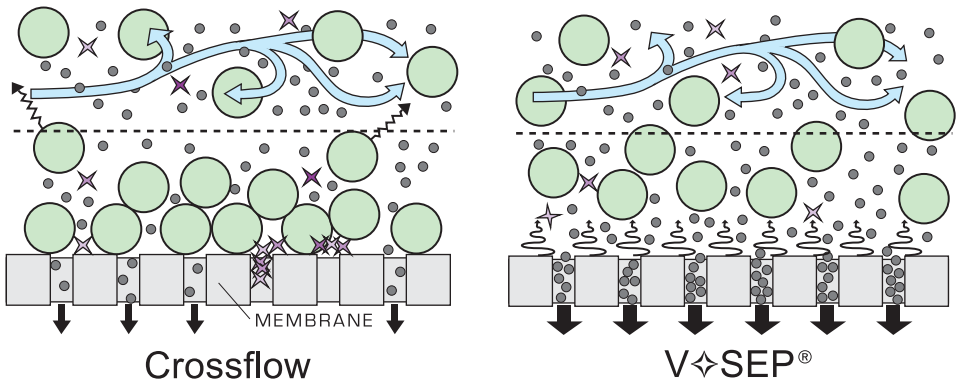
In order to overcome these limitations, a vibrating membrane system called VSEP (Vibratory Shear Enhanced Process) was created by New Logic Research of Emeryville, California. Rather than simply reducing solids loading by pumping at high velocity, VSEP eliminates membrane blinding by vibrating the membrane surface at extremely high frequency. This vibration produces shear waves that propagate sinusoidally from the surface of the membrane. This increase in the shear energy produces 5-15 times higher rates of filtration and makes membrane separations possible for very concentrated or viscous materials.

> ***"VSEP has made it possible to dewater or separate high solids applications previously not possible with conventional mebranes."***

The industrial VSEP unit contains hundreds of sheets of membranes, which are arrayed as parallel disks separated by gaskets. The disk stack is contained within a fiberglass reinforced plastic cylinder (FRP). This entire assembly is vibrated in torsional oscillation, similar in principle to the agitation of a washing machine.

VSEP can produce extremely high shear energy at the surface of the membrane. The membrane module is attached to a spring assembly and moves at an amplitude of 7/8" peak-to-peak displacement, and oscillates between 50 and 55 Hz. The fluid is gently pumped through the module while a highly focused shear zone at the surface of the membrane is created by the resonating oscillation. Rejected solids at the membrane surface are repelled by the shear waves and flow to the bottom of the module becoming more and more concentrated until exiting the system.

VSEP has made it possible to dewater or separate high solids applications previously not possible with conventional membranes. This has created opportunity in the chemical processing industry for a technologically advanced separation device that can efficiently and economically process specialty chemical products. The following are just a few examples of successful installed VSEP membrane systems used today.



VSEP overcomes fouling problems commonly associated with membrane filtration by using vibration to create high shear at the membrane surface.

Polymer concentration and diafiltration

VSEP is used successfully in a process known as "diafiltration". Many chemical products are the result of an aqueous chemical reaction. During the process the desired product is created along with other unwanted ingredients. In order to meet market requirements, the impurities must be separated from the final product. Very often this purified solid will be a product that has significant value. During the VSEP membrane process, the liquid is filtered so that one ingredient is held back by the membrane and one is allowed to pass through as filtrate. Clean water is added to the system, which continually dilutes the contaminants as filtrate and is removed from the filter module. Diafiltration gradually improves the quality of the retained species by washing away impurities. This purification can go on infinitely, but normally there is a target level of acceptable impurities and the wash volumes are calculated to reach this target.

Since polymers are man made substances, stability of the hydrocarbons is a key factor to processing suitability. As a thermoplastic resin, polymer latexes are made as a liquid and usually the final product is a solid or a high molecular weight compound. The key is to keep the product stable through the manufacturing process. The hydrocarbon monomers are reacted in an aqueous solution to form complex chains. Once the monomers have been consumed and the polymer is in the correct formulation, it must be dewatered. Conventional methods for this are Evaporators, Spray Dryers, and Rotary Vacuum Drum Dryers. VSEP is able to concentrate the stream to approximately 25-55% solids depending on the polymer, therefore reducing the load on existing evaporative methods.

Because the polymers must be reacted in a dilute solution, a great volume reduction by dewatering must be accomplished to get the desired product. With the VSEP process, one piece of equipment is used for the entire process.

Actual polyphosphate sample run through a VSEP filtration system.

Phosphate clarification

A VSEP membrane filtration system installed at a major chemical fertilizer production facility is used to clarify Phosphate feedstock for a high value fertilizer. The VSEP system employs a Microfiltration membrane module with special construction for service with high temperature and low pH.

VSEP Filtration is used to remove Calcium Sulfate and other suspended solids from the Phosphoric Acid and is also used to remove contaminants after the reaction with Ammonia to form Ammonium Phosphate. The VSEP Microfiltration high temperature membrane module is capable of treating phosphoric compounds and providing a filtrate that is free from suspended solids. The VSEP process does not involve any chemical addition and is operated in an automated single pass mode. Both the Permeate and Concentrate are sold as products.

Pulp & paper mill effluent treatment

VSEP provides an alternative approach to effluent treatment for "end of pipe" applications. In a single process step, VSEP will reduce BOD, COD, TSS, TDS and color to provide a high quality stream for discharge or reuse in the paper making process. In many applications, the addition of VSEP will eliminate conventional treatment processes without requiring chemical treatment.

Using VSEP ultrafiltration followed by a VSEP nanofiltration module is a commercially viable option for end of pipe treatment at this paper mill. Nearly 95% of the feed wastewater is recovered as clean water suitable for reuse or discharge, while less than 5 % is discharged as concentrate.

Oil refinery desalter effluent treatment

VSEP has been used successfully to treat desalter effluent and blowdown. Handling of suspended solids coming out of the desalter is a common problem for existing on-site wastewater man-

agement facilities, particularly during blowdown. VSEP can remove 100% of suspended solids with no chemical pretreatment during normal operation or blowdown, providing a 98% recovery in the form of clear filtrate. Even during a desalter upset, VSEP is able to filter the crude oil as well as suspended solids. Even difficult to work with "opportunity crude" presents no problems to the VSEP system. Particulate-free permeate continues on to waste treatment while concentrated sludge is burned in the coker.

In many locations, desalters are the bottleneck of the refinery, due to the burden they place on the waste treatment facilities. With VSEP, this burden is eliminated resulting in a significant increase in production throughout the refinery. In some cases, the return on investment can be measured in days, not years.

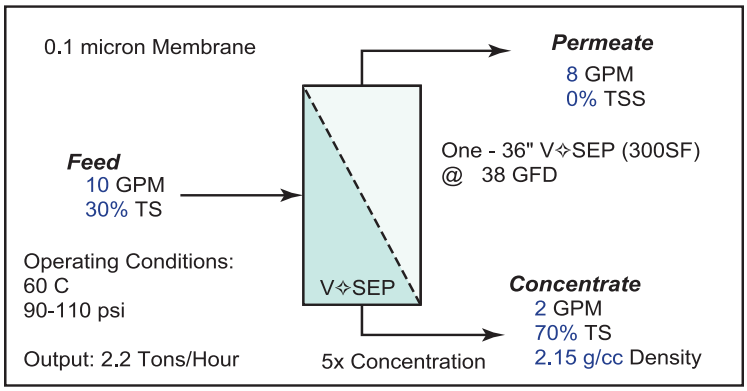
Iron oxide desalting

In the case of Iron Oxide, VSEP is used in the diafiltration process to wash away salts and then to dewater to more than 36% solids in a single pass. This level of solids is nearly the gel point of iron oxide, so the diafiltration process is performed at 11% solids for maximum efficiency. Operating at this solids level results in a high rate of filtration with a minimum amount of wash water used. This is the important balance in any diafiltration process. During diafiltration, an ultrafiltration membrane is used, which will reject the pigment particles and allow the salty water to pass through the membrane. By successive rinses, the pigment can be nearly completely separated from the salt in solution.

PVC latex concentration

New Logic has installed its VSEP membrane filtration system at major international latex manufacturing facilities in Europe and Asia. In this process, VSEP is used to concentrate Polyvinyl Chloride (PVC) latex ahead of a spray dryer. The VSEP system uses an ultrafiltration membrane module and is able to concentrate latex emulsions from an initial concentration level of 38% total suspended solids up to 55-60%. VSEP is capable of dewatering slurries nearly up to the gel point of the material. In this case, a dry PVC Latex is the final product, so the spray dryer is used to take the thick emulsion slurry from the VSEP and convert it to a dry powder by flashing the remaining water content.

Spray dryers are expensive to buy and to operate; installation of a VSEP system means a smaller spray dryer can process more product and consume less energy in the process. In many cases, spray dryers are working at capacity. Once the VSEP system is installed, energy consumption is drastically reduced and total plant capacity is increased by a factor of 2 to 3. Even if a plant capacity increase is not needed, the VSEP can be used as pretreatment for the spray dryer and will cut energy consumption costs by more than half.



A typical Titanium Dioxide Flow Diagram.

Titanium dioxide dewatering

During the refining and calcination process, TiO2 is suspended in an aqueous slurry. This slurry must be dewatered; TiO2 product is shipped as dense, thick slurry or a dry powder. The initial slurry, which is about 30% TiO2 by weight must be dewatered to about 70%. VSEP is uniquely able to dewater concentrated slurries to 70% solids in a single pass using an ultrafiltration membrane. In addition to the processing of TiO2 product, VSEP is an excellent solution for wash down water to recover the product that is normally lost during operation and transport. The VSEP system is used to replace or supplement the evaporator/dryer at the facility to increase the plant's energy efficiency and reduce operating costs.

Colloidal silica washing and concentration

Sand is fused with Sodium Carbonate in a high temperature furnace and the result is Sodium Silicate and Carbon Dioxide gas. Adding Sulfuric Acid makes Silica Gel. The result is an aqueous salty solution containing Silica colloids. The Sodium Sulfate salts must be removed and then the Silica must be partially dewatered.

VSEP has been installed and used as an efficient method to dewater colloidal silica in a single pass. During initial diafiltration, an ultrafiltration membrane is used to reject the silica particles and allow the salty water to pass through the membrane. By successive rinses, the silica can be completely separated from the salt solution. VSEP has been used to replace expensive centrifuge systems and to increase product quality and output.

Carbon black desalting

Carbon Black is a name for a family of non-crystallized Carbon forms. It is obtained from the incomplete combustion of hydrocarbons and becomes the byproduct of combustion known as "Soot". Once the soot has been formed it is air blasted or scraped off into a collection area. In its raw form, all soot deposits will have impurities that need to be removed.

During the VSEP diafiltration process, the raw soot is washed in an acid bath. Successive filtration and washes with water, or diafiltration, is used to remove impurities. Once the diafiltration processing is complete, the slurry must be dewatered to 70% solids or higher. Some finished product is shipped as a 70% slurry. Other product is further dried and shipped as a dry powder. In either case, the initial slurry that is about 5% Carbon by weight is dewatered to at least 70% using VSEP's ultrafiltration membrane process.

Fuel ethanol recovery

Removing the solids during the production of ethanol from biomass can be very difficult and costly. The leftover solids from Ethanol production must be removed from the aqueous stream in order to have any value as incinerator fuel. VSEP is specifically designed to handle high solid streams and can efficiently process bio-ethanol streams.

The main advantage of VSEP in the production of bio-ethanol is that the permeate is free of suspended solids, which increases the efficiency of distillation and reduces operating costs. Additionally, VSEP provides several key advantages over other technologies. First and foremost, the VSEP technology is the only system that can generate a totally solids-free permeate prior to or after distillation and achieve a high level of solids concentration. Furthermore, VSEP works with no chemical addition. When compared to other membrane technologies such as tubular membrane systems, VSEP has the advantage of being able to tolerate (and also concentrate) high levels of suspended solids. While tubular membrane systems can handle higher levels of suspended solids then conventional spiral elements, they are unable to reach the same level of solids concentration as VSEP.

Managing process variables

Managing a plethora of process variables is the job of any chemical processing engineer. Monitoring data that is subject to change and fluctuation can be a full time job. With so many process variables, it can often be difficult to troubleshoot a problem and keep a handle on the situation. Time, temperature, pressure, pH, solids content, chemical compatibility, additive addition, flow rates, and even the expertise of the operator all can affect the final product quality. In the end, every production facility needs to be able to produce consistent and uniform product that never changes unless it can be improved in some way. Failing to account for and manage these variables can lead to product losses and inferior product quality. Any change upstream in manufacturing can have serious effects on this very dynamic process. Using membrane separation can improve process predictability dramatically.

Separation Technology Cost Analysis

	Capital Cost	Operating Cost	Installed Cost	Footprint
Evaporators	$$$$$	$$$$$	$$$$$	large
Biological Systems	$$$$$	$$$$$	$$$$$	large
Crossflow Filters	$$$$	$$$$	$$$	large
Centrifuges	$$$	$$$	$$$	small
V✧SEP®	$$	$	$	small

VSEP's automatic operation and small footprint are among its advantages over traditional separation technologies.

The driving force behind the expansion of membrane use has been tighter and tighter controls on product quality and discharge limits. Membranes are precise and accurate tools that will yield a predictable result. Membranes are made according to specification and can be constructed using various polymers made with specific pore size ratings or rejection characteristics. Once made and put online, the permeate quality from operation is consistent. The selectivity of membranes is not dependent on the dosing of chemicals, the expertise of the operator, or any other mitigating factor. The extremely fine selectivity of membranes allow for a significant reduction of the impact of varying process conditions when it comes to the end result of the separation.

VSEP: an engineered solution

The VSEP membrane filtration system has been designed specifically for the chemical processing user. The systems are completely automated, compact, and reliable.

V✧SEP® Advantages

1. High filtration rates
2. Fouling resistance
3. High solids
4. High efficiency
5. Engineered dependability
6. Compact design
7. Convenient testing
8. Low cost

With very few moving parts, maintenance is simplified. Each VSEP system is custom designed for a particular application, with special materials of construction including exotic alloys and thermoplastics available to fit any job.

The VSEP is a completely integrated "Plug and Play" system requiring only process in and process out connections during installation. The system is controlled using a sophisticated Allen Bradley Industrial Computer that monitors data and implements the program functions in a seamless and automatic process. The VSEP controls are compatible with plant Distributed Control Systems (DCS) and can be operated as stand-alone devices or as a component of a much larger process system.

One of the most important considerations in plant design or in considering upgrades to an existing plant is the footprint of the system considered. VSEP membrane systems are inherently small in footprint and being modular, can be rearranged to fit irregular shapes and areas available.

Typically, VSEP can be installed without any modifications to the building or structure. The VSEP is able to use space very efficiently due to its intrinsic vertical design and lack of need for pretreatment or other ancillary equipment. A typical VSEP system can be installed in a small room. When compared to evaporators, clarifiers, or filter press units, choosing VSEP can result in dramatic construction cost savings for the new facility improvements needed to house the system.

More productivity please

Keeping up with the industry standard of 3 to 6 percent annual productivity growth can be challenging. Recent advances in technology have yielded dramatic improvement to worker productivity and have also enabled more automation in the process. These kinds of productivity improvements are becoming saturated and are beginning to show diminishing returns. In order to keep up, other methods and technologies will be needed to continue the trend of productivity improvements.

VSEP provides a proven technological solution for productivity improvements. Many conventional separation processes are highly labor dependent, being run in batches or needing constant operator attention to monitor process conditions. Many types of equipment are replete with moving parts that require constant lubrication, modification, and rebuilding. Keeping some of this equipment running can require the aid of a small army of workers. VSEP is run as a stand-alone automatic device that self modulates and is programmed for independent operation. The system is run in single pass mode with consistent throughput in and throughput out without the need for operator manipulation. Because there are very few moving parts, maintenance is limited and not rate limiting.

Managing environmental concerns

New regulations have arrived affecting discharge of waste product from manufacturing. The Clean Water Act and pending Arsenic Regulations are just two examples. In addition, water is becoming a more valuable resource due to strained infra-

structure for water delivery. In order to deal with new regulations, many facilities are attempting to implement a Zero Discharge program. This can be the best of both worlds when water is reused in the process and hazardous materials are recovered for proper disposal or reuse in the operations. Very often, valuable product is part of the discharge; this product can be recovered and added to the bottom line.

Membrane filtration offers the ultimate in wastewater treatment; the results often exceed even the most stringent regulations. Membrane separation is precise and predictable. No chemical addition is required and consistent results can be attained. In the case of PVC manufacturing, the filtrate from the VSEP membrane system is so clean that re-use is an option. If necessary, PVC process water run through a VSEP membrane filtration can exceed even the strictest EU regulations on discharge of chlorinated hydrocarbons.

In other polymer manufacturing operations, including Methyl Cellulose, Polyvinyl Acetate, Styrene-Butadiene Rubber, and Acrylonitrile-Butadiene Rubber, VSEP has been proven to effectively treat manufacturing wastewaters and comply with discharge regulations. In most cases, the treatment of the wastewater to prevent discharge of chlorinated hydrocarbons results in recovery of this valuable product for reintroduction to the process.

In the pigment and minerals processing industry, lagoon storage basins are used to hold wastewater that contains valuable pigment product. These storage basins are large and can be difficult to manage during rainy periods. While discharge from these if often not hazardous, any release is undesirable and can affect neighbor relations in the surrounding area. VSEP membrane filtration has been used for many years in the treatment of Calcium Carbonate, Chromium Blue, Bentonite Clay, Titanium Dioxide pond water and wash down water from operations. For many companies, VSEP is the heart of their Zero Discharge and product recovery solution.

Reducing energy costs

Most conventional separation techniques used in chemical processing such as evaporation, distillation, centrifugation, and spray dryers have very high energy demands and costs associated with them. Membrane filtration and VSEP in particular are very energy efficient when it comes to liquid-solid separation. Each VSEP module consumes about 10 hp of energy plus about 5 hp for feed pumps to deliver the liquid during filtration. As an example, one VSEP chemical processing customer has realized cost savings of $269,000 per year when installing a single industrial VSEP unit to dewater 40 gpm of polymer ahead of a spray dryer (@ 0.32 $/Therm). In addition, water that is reused will retain and bring with it the heat from the processing operation. Recovery of warm water can result in less boiler demand and reduced cost of heating incoming water.

Proven V✧SEP® Applications

✓ Chemical Processing	✓ Manufacturing
✓ Mining	✓ Petroleum Processing
✓ Paints & Pigments	✓ Pulp & Paper
✓ Pure Water	✓ Wastewater

Conclusion

In a single package, the VSEP vibrating membrane filtration system can provide a higher value chemical product, reduce energy consumption, provide filtrate that meets strict environmental regulations, and recycle clean water for reuse in operations. With VSEP's enabling technology, chemical processing plants can increase production quantity and quality, meet tighter environmental regulations and save money at the same time.

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~~filter press~~
~~clarifier~~
~~DAF~~
~~centrifuge~~
~~evaporator~~
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V✧SEP®

The engineer's choice for liquid-solid separation

Before you buy a traditional separation technology, consider the V✧SEP vibrating membrane system.

V✧SEP requires **no pretreatment** and can handle liquid-solid separations at **any pH**, and at temperatures **up to 120˚C** while producing a crystal clear permeate and a viscous sludge in a single pass. Add to this a small footprint, **low power consumption**, and the fouling resistance of vibration, and it becomes clear why for over 15 years, engineers have relied on V✧SEP for their volume reduction and separation needs.

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