

Exhibit Q:

V ✧ SEP Filtration of Acid Mine Drainage

V◇SEP Filtration of Acid Mine Drainage

A cost-effective and efficient processing solution

Overview

Since their development as lab filters in the early 1960s, polymeric membranes have grown in the number of uses at exponential rates. Membrane architecture and process design itself has undergone significant advancement. A unique membrane filtration system, known as V◇SEP (Vibratory Shear Enhanced Process), was developed by New Logic of Emeryville California. The technology employs vibrational oscillation of the membrane surface to improve the relative throughput per area of membrane used. This oscillation is used to prevent colloidal fouling of the membrane surface.

One unique benefit of the shear created by vibrational oscillation is the resiliency of the membrane system against fouling from crystallization of mineral salts. Studies recently conducted have shown that crystallization occurs out in the boundary layer of suspended solids as filtrate is removed and solubility limits are reached. Once precipitated, these insoluble mineral salts become just another suspended solid and can be easily washed from the membrane system with laminar crossflow of the process feed.

With conventional static or crossflow filtration subject to colloidal fouling, mineral scale formation would severely inhibit performance. As a result, these membranes have low tolerance for mineral hardness and would require elaborate pretreatment and chemical dosing to inhibit crystal formation using antiscalants. Even with pretreatment and chemical dosing, conventional membranes would be limited in the % recovery of filtrate that is possible.



It is because of this key limitation that membranes have not been used to a great degree in the processing of Acid Mine Drainage, until now. New Logic's V◇SEP has the ability to perform membrane separations not possible using conventional membrane systems. Wastewater treatment systems that are compact, economical, and reliable are now possible for the mining industry.

Mining Regulation

One of the challenges of today's mining operations is that heavy metals which pose a potential environmental hazard are naturally occurring elements in the ore that is removed for processing. For a typical Copper mine, one ton of waste rock can contain several pounds of copper, five ounces of zinc, three ounces of lead, and two ounces of arsenic. On average, the earth's crust has background levels of about 2 ppm of arsenic. Limits currently exist for heavy metals in industrial wastewater discharge. As a result of the Clean Water Act, the

EPA is currently developing new tighter regulations on these metals. Since the average soil contains 2 ppm of arsenic, almost any water that has come in contact with soil and is then discharged to sewer could violate the new regulations.

Current EPA Target Limits for Discharge:

Regulated Metal	Symbol	Monthly Ave.
Cadmium	Cd	0.09 ppm
Chromium	Cr	0.55 ppm
Copper	Cu	0.58 ppm
Lead	Pb	0.09 ppm
Manganese	Mn	0.10 ppm
Molybdenum	Mo	0.49 ppm
Arsenic	As	0.05 ppm
Nickel	Ni	0.64 ppm
Silver	Ag	0.06 ppm
Tin	Sn	1.40 ppm
Zinc	Zn	0.17 ppm

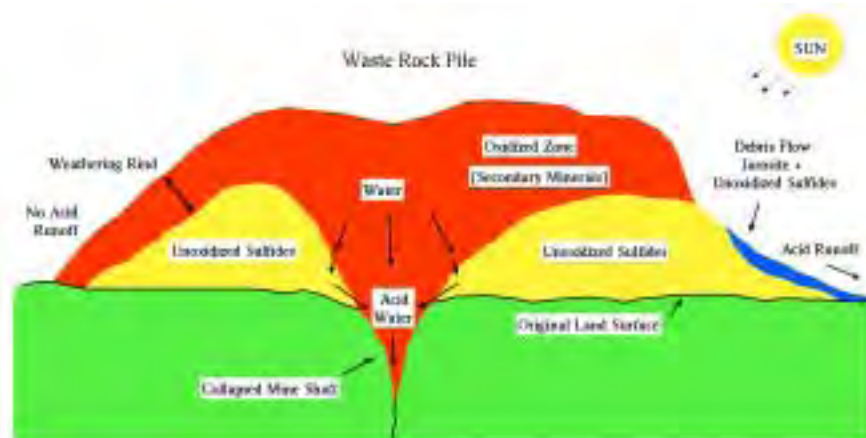
The EPA is considering new industrial discharge regulations as a result of the "Clean Water Act"

The mining industry is one of the most heavily regulated by the EPA. Mining does nothing at all to increase the amounts of naturally occurring substances in the rock. Ore removed for processing can contain nearly all of the 650 elements and chemicals regulated as hazardous waste by the EPA. Unfortunately, the simple act of moving it from one place to another qualifies as a "release to the environment."

If you take the parts per million concentrations of controlled substances in the waste rock and multiply them by an average mine's daily tonnage of rock mined, the amounts increase dramatically. A copper mine's total "release" of all TRI reportable chemicals can be approximately 450 million pounds of hazardous materials per year. With the current laws, it makes no difference whether the materials are released to the environment or are stored in government permitted waste rock repositories and tailing impoundments. Either way the movement of the earth must be reported as a "release to the environment"

Many mining companies are forced to clean up historic wastes from mining in the 19th century. Again, the act of moving this material constitutes a "release" according to the EPA's method of reporting, even though the historic mining wastes are being placed in state or federally-approved impoundments that are safer for the environment than if the wastes remained in their current location.

The problem can be even more difficult if the mining involves rare earth metals where Uranium, Radium, or other radioactive elements can be found. As long as the radioactive elements are not disturbed, there is not classification



The Life Cycle of Acid Mine Drainage

as a hazardous material that needs superfund attention. But if the rock is moved from one place to another, a release of radioactive materials has occurred and must be reported.



Copper Ore from Arizona

Copper Mining Process

Rocks are blasted to break them into smaller pieces and loaded into large trucks for transport to the processing locations. The ore goes either to concentrating and smelting or to leaching and electrowinning. It depends on how much copper and the types of minerals it contains.

In one copper production process, rock that comes from the mine is crushed into smaller and smaller pieces by heavy steel balls in machinery called mills.

Concentrating Ground up rock is mixed with water, air bubbles and small amounts of chemicals. The chemicals allow copper minerals to rise to the top and stick to floating air bubbles. The remaining mixture of crushed rock and water - called tailing - separates from the copper bearing bubbles. The copper minerals are skimmed off and dried to form copper concentrate, a powder-like material.

In the smelter, copper concentrate is melted and copper is separated from other substances in the concentrate. Molten copper is poured into molds called anodes. The unwanted material cools to a glass-like substance called slag. The natural metals that remain in slag are reported under EPCRA.



Processed Gold Ingot

In an alternate copper production process, rock is taken from the mine directly to stockpiles. A solution of slightly acidic water is dripped on the stockpiles, percolating down through the rock and dissolving copper along the way. The solution containing the copper is collected and piped to holding ponds. In tanks, the copper-bearing solution is mixed with chemicals that transfer the copper to a more concentrated solution called electrolyte. The electrolyte is pumped to steel tanks. Starter sheets hang in the solution and, using an electric current, the copper is plated from the electrolyte on to the sheet, forming 99.99 percent pure copper plates. All solutions used during this process are recycled. Producing copper and other hard metals also takes a lot of water, which is why water management is such a crucial part of any mine's operations.



Copper Ore being Loaded



“Electrowinning” - is electroplating of dissolved copper onto metal anodes using electrical current

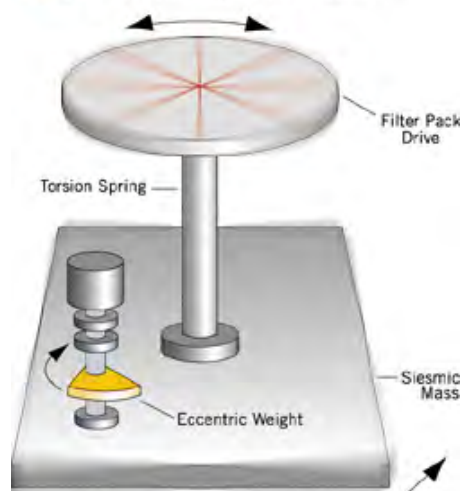
Finished Copper Anodes ready for transport as sale

Vibratory Shear Process

V \diamond SEP's unique separation technology is based upon an oscillating movement of the membrane surface with respect to the liquid to be filtered. The result is that blinding of the membrane surface due to the build up of solids is eliminated and free access to the membrane pores is provided to the liquid fraction to be filtered. The shear created from the lateral displacement caused suspended solids and colloidal materials to be repelled and held in suspension above the membrane surface. This combined with laminar flow of the fluid across the membrane surface keeps the filtered liquid homogeneous and allows very high levels of recovery of filtrate from the feed material. In the case of Acid Mine Drainage, up to 97% of the water can be filtered in a single pass filtration using V \diamond SEP. Flux is inversely related to % recovery, so the optimum % recovery may vary for each application. Other methods like filter presses are done in batch mode with operators opening and cleaning the filter cake on a regular basis. V \diamond SEP is a continuous automated process requiring very little operator attendance.

The industrial V \diamond SEP machines contain many sheets of membrane, which are arrayed as parallel disks separated by gaskets. The disk stack is contained within a Fiberglass Reinforced Plastic (FRP) cylinder. This entire assembly is vibrated in torsional oscillation similar to the agitation of a washing machine. The resulting shear is 150,000 inverse seconds, which is ten times greater than the shear in crossflow systems. High shear has been shown to significantly reduce the fouling of many materials. The resistance to fouling can be enhanced with membrane selection where virtually any commercially available

V \diamond SEP Resonating Drive System



An eccentric weight induces a wobble that resonates at about 50 Hz giving vibration to the Filter Pack above

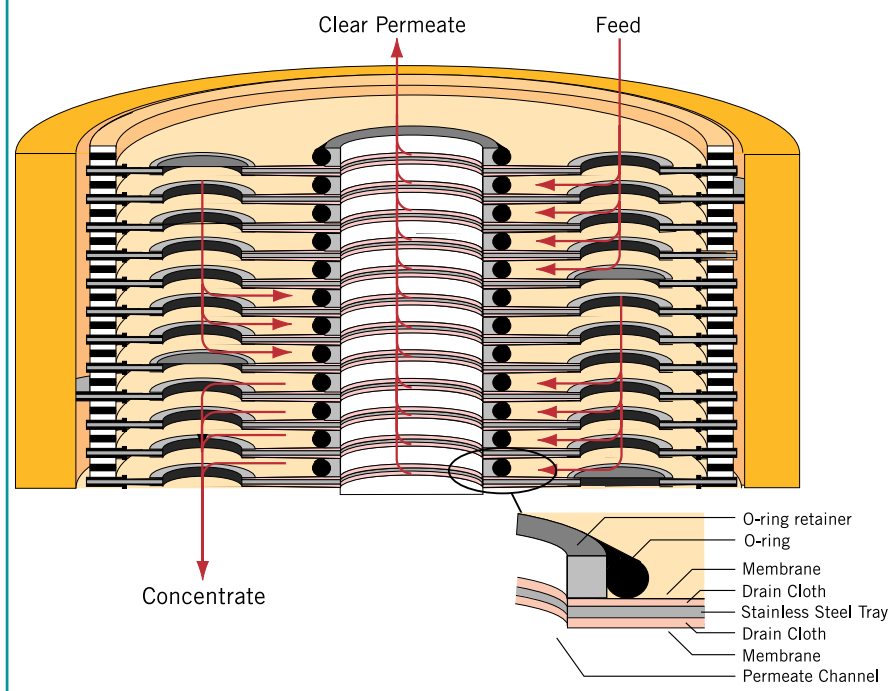
membrane materials such as polypropylene, Teflon, polyester, and polysulfone can be used.

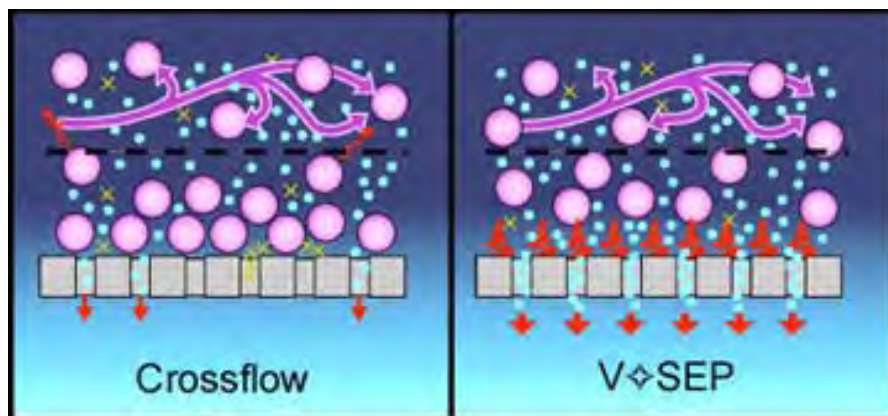
Each Series i system contains up to 2000 square feet of membrane filtration area. A single V \diamond SEP unit is capable of processing from 5 to 200 U.S. gallons per minute while producing crystal clear filtrate and a concentrated sludge in a single pass. This large throughput capability can be accomplished with a system, which occupies only 20 square feet of floor space and consumes 15 hp.

Conventional vs. V \diamond SEP

The main difference between V \diamond SEP and traditional crossflow membrane filtration is the mechanism by which the foulants are prevented from accumulating on the membrane surface. A traditional crossflow system relies on

Filter Pack Cross Section





An illustration showing the shear energy at the membrane surface for conventional crossflow systems and for V-SEP

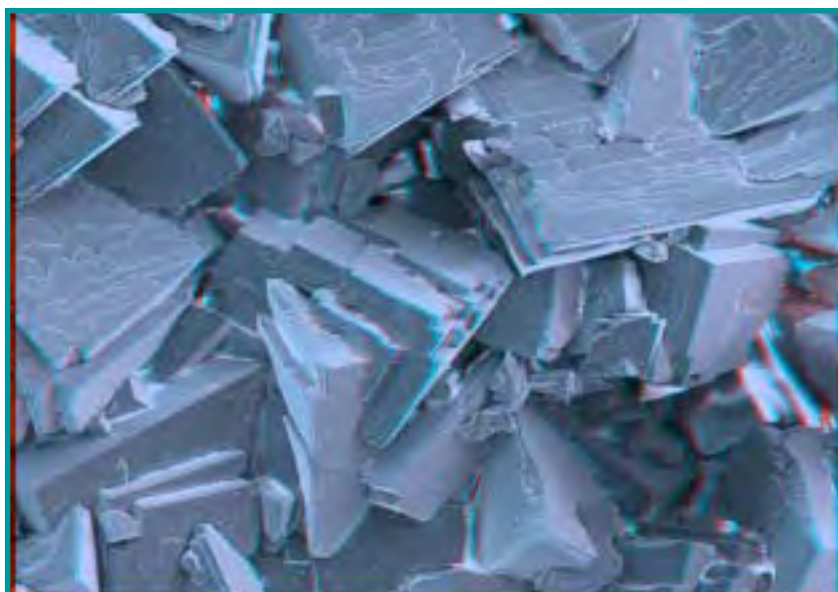
the fluid velocity of the feed material alone to create shear forces needed to reduce fouling. This mechanism assists in slowing the fouling process but because a thin, stagnant boundary layer remains on the membrane surface, the foulants from the stream will accumulate over time and deteriorate the throughput rate. On the other hand, a V-SEP system utilizes a patented vibratory drive mechanism that vibrates the membrane surface creating a shear force that disrupts the boundary layer. The resulting motion of the vibration drive is a 3/4 inch peak to peak displacement, which constantly repels solids and other foulants away from the membrane surface. This mechanism enables the filter module to maintain higher, sustained throughput rates and process larger volumes of material economically. Rather than simply preventing fouling with high-velocity feed, V-SEP reduces fouling by adding shear to the membrane surface with vibration. This vibration produces shear waves that propagate sinusoidally from the membrane's surface. As a result, the stagnant boundary layer is eliminated which increases the filtration rates.

Scaling Resilience of V-SEP

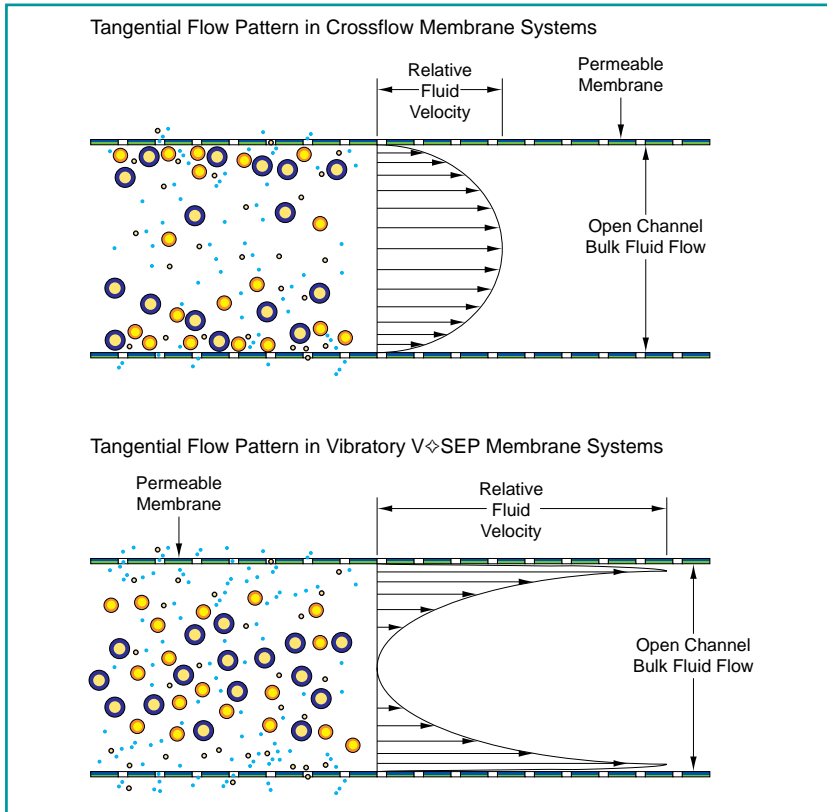
Torsional oscillation is a very effective method of colloid repulsion as shear waves from the membrane surface help to repel oncoming particles. The result is that suspended solids are held in suspension hovering above the membrane as a parallel layer where they can be washed away by tangential crossflow. This washing away process occurs at equilibrium. Pressure and filtration rate will

determine the thickness and mass of the suspended layer. Particles of suspended colloids will be washed away by crossflow and at the same time new particles will arrive. The removal and arrival rate will be different at first until parity is reached and a state of equilibrium is reached with respect to the boundary layer.

This layer is permeable and is not attached to the membrane and is actually suspended above it. In V-SEP, this layer acts as a nucleation site for mineral scaling. Mineral scale that precipitates will act in just the same way as any other arriving colloid. If too many of the scale colloids are formed, more will be removed to maintain the equilibrium of the diffusion layer. Conventional membrane systems could develop cakes of colloids that would grow large enough to completely blind the membrane. In V-SEP, no matter how many arriving colloids there are, and equal number are removed as the diffusion layer is limited in size due to the gravitational pull (G forces) of the vibrating membrane.



Calcium Carbonate Crystals



High fluid velocity and shear energy at the membrane surface inhibits mineral salt crystallization

One other significant advantage is that the vibration and oscillation of the membrane surface itself inhibits crystal formation. Just as a stirred pot won't boil, lateral displacement of the membrane help to lower the available surface energy for nucleation. Free energy is available at perturbations and non-uniform features of liquid/solid interfaces. With the movement of the membrane back and forth at a speed of 50 times per second, any valleys, peaks, ridges, or other micro imperfections become more uniform and less prominent. The smoother and more uniform a surface, the less free energy is available for crystallization. Crystals and scale also take time to form. The moving target of the membrane surface does not allow sufficient time for proper germination and development.

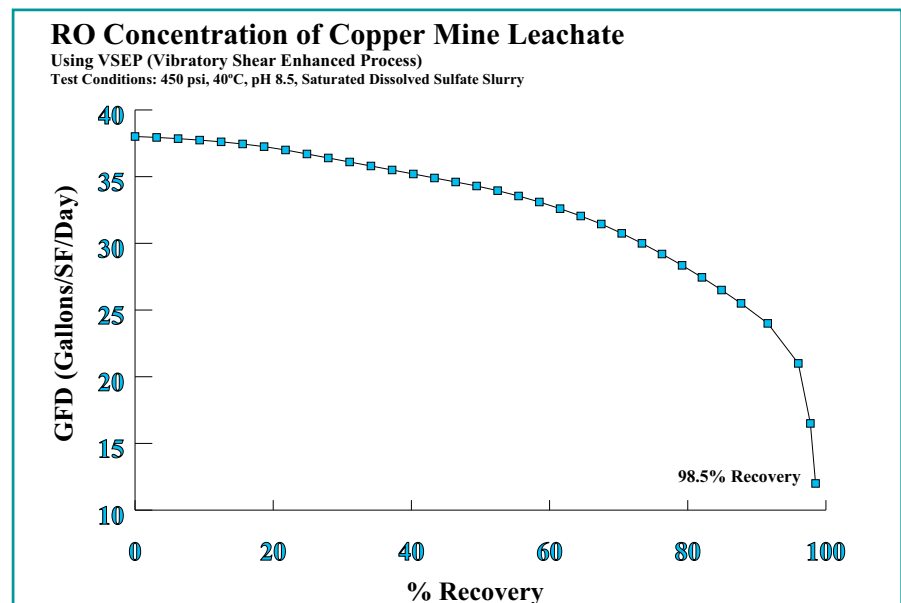
Other stationary features within VSEP present a much more favorable nucleation site. Whereas, with conventional membranes that are static, scale formation on the

membrane is possible and has plenty of time to develop and grow.

Results using VSEP

VSEP's Reverse Osmosis membrane module is capable of treating Acid Mine Drainage and providing a filtrate, which is free from suspended solids and low in Sulfates and Heavy Metals. The VSEP process does not involve any chemical addition, except for pH adjustment using Lime, and meets the process engineers' needs for automated PLC controlled production. VSEP modules containing about 1300 SF (120m2) of filtration media are modular and can be run in parallel as needed to meet any process flow requirements.

Each 84" VSEP module can produce 20 gpm of clean water from the leachate pond. Since the units are modular and can be used in parallel or in series, the number of VSEPs needed can be calculated based on the amount of material to be processed, (GPD or GPM). At 40°C the membrane flux is about 20-



30 GFD (Gallons per Square Foot per Day). System throughput is also a function of the extent to which the feed is concentrated.

Process Description

The mining leachate is collected and stored in holding tanks. Lime is added to raise the pH and to precipitate calcium sulfate and other slightly soluble mineral salts prior to filtration. After proper residence time, the Feed Liquor is pumped into the V \diamond SEP system for filtration. The viscosity of the material plays a big part in the rate of filtration. Heat will help to decrease the viscosity of the slurry and therefore improves the throughput of the V \diamond SEP system. Counter-current heat exchangers and recovery boilers are used to warm the feed material.

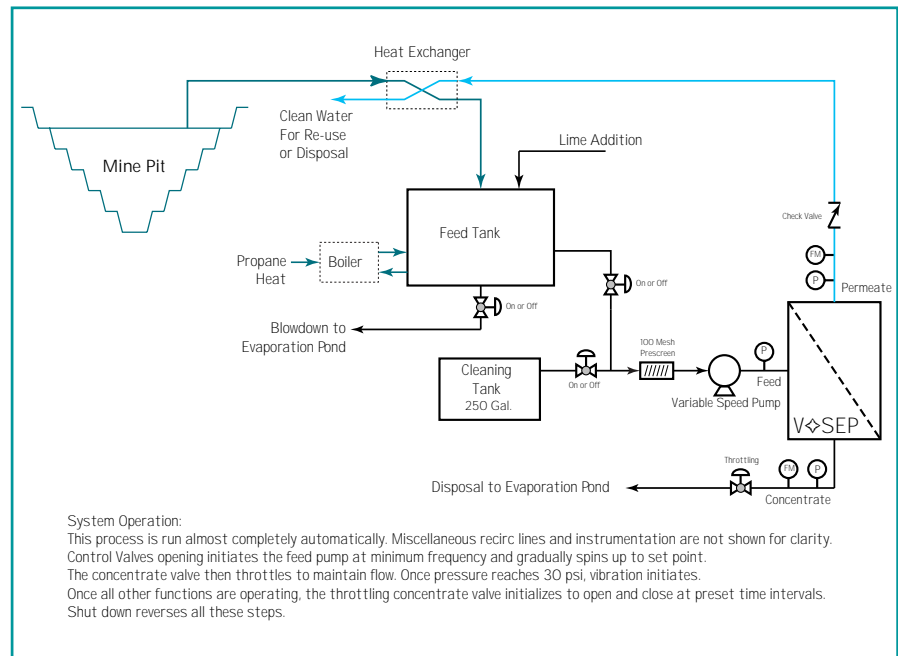
The heated leachate is pumped into the V \diamond SEP Filter Pack at about 450-psi. The contents of the feed tank are taken out of the side of a cone bottom tank so that settled solids are excluded. The resulting permeate is sent to a process water storage tank for reuse in the operations. The reject material, about 15% of the volume, is sent back to the leachate pond or on to evaporation ponds for disposal.

When the permeate rate drops off, the Filter Pack is cleaned using New Logic's formulated membrane cleaners out of a Clean in Place tank of about 260 gallons. Cleaning solution is recirculated with pressure and vibration to dissolve foulants that have found their way to the membrane. Actual site conditions at various mine locations have shown that the membrane can be cleaned easily and the results from week to week are predictable and stable.

Table 1: Acid Mine Drainage Sample Analysis

	Untreated	Limed	V \diamond SEP*
TDS	10,000 ppm	3,000 ppm	240 ppm
pH	2.7	8.5	8.5
Calcium, Ca	490 ppm	600 ppm	36 ppm
Magnesium, Mg	420 ppm	350 ppm	18 ppm
Sodium, Na	70 ppm	70 ppm	6 ppm
Iron, Fe	1,100 ppm	0.1 ppm	<0.1 ppm
Manganese, Mn	182 ppm	3.6 ppm	<0.1 ppm
Copper, Cu	186 ppm	<0.1 ppm	<0.1 ppm
Zinc, Zn	550 ppm	<0.1 ppm	<0.1 ppm
Sulphate, SO4	8,000 ppm	2,000 ppm	100 ppm

*40°C, 85% Recovery, 450 psi

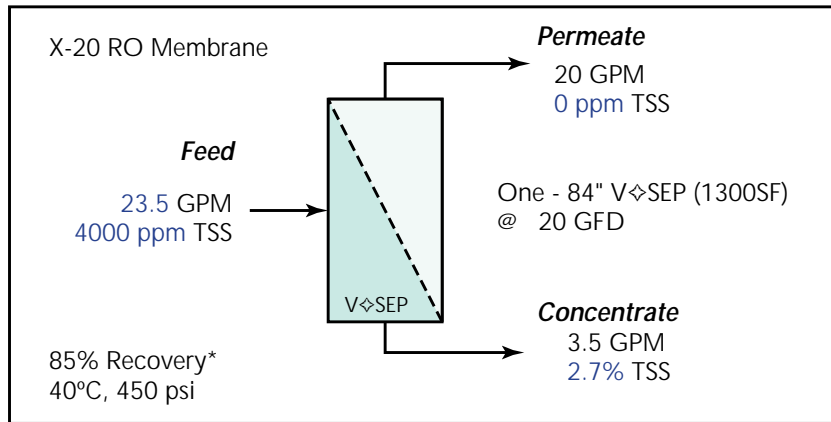


Process Flow Diagram for a typical V \diamond SEP Installation



Case

Study



*Recoveries up to 97% can be done with reduced throughput

Mining Leachate Options

EPA may not even consider data from treatment systems that exceed 50 mg/L of total suspended solids (TSS). If your results are well under 50 mg/L with your current discharge, a metals spectrum analysis should be done to determine compliance.

Wetlands & Natural Bioremediation

Suitable as treatment, but requires large areas of land and huge amounts of water that may not be readily available in arid western states. In addition, there are environmental risks that still linger as leaching into groundwater and local wellwater systems are a considerable liability. In addition, wildlife and habitat can be at risk of exposure to heavy metal poisoning.

Chemical Flocculation/Clarification

The drawbacks with this option will be the uncertainty of the final discharge amounts of the various metals over the long term. Variations in the effectiveness of the chemical precipitation and throughput to the clarifier leave open the possibility of process upsets and fines.

Ion Exchange Resins

An effective treatment system, but cannot handle more than 500 ppm TDS and therefore must be used in tandem with other pretreatment systems.

Conventional Membrane Systems

Also suffer from limits on TDS, TSS, and organic constituents. Depending on the process conventional membrane systems would be a part of a multi stage treatment process. Also, crossflow systems will require high fluid velocity to avoid diffusion polarization of the membrane and consequently reduced flux. The result of this is poor % recovery of filtrate, which can be sewerred. The reject from conventional membrane systems could be further treated by yet another treatment process or hauled as waste. Since operating costs such as hauling are part of any equipment purchasing decisions, the % recovery with crossflow filters is not very attractive.

System Components

The V-SEP system is configurable for manual mode where the operator would initiate operating sequences, or for full automation including seamless cleaning operations with round robin cleaning or multiple units. The V-SEP has a PLC (Programmable Logic Controller) which monitors pressure, flow rate, and frequency. It also provides the safety in operation by monitoring conditions and initiating an alarm shut down should some configurable parameters be reached. The control stand contains the PLC, Operator display and terminal strips for wiring connections to instrumentation.

X-20™* Reverse Osmosis Membrane

Composition	Polyamide Urea
Nominal Salt Rejection	99.0%
Operating Pressure	0-600 psi
Continuous pH Range	4-11
Max Flat Sheet Temp	60°C

*X-20 is manufactured by TriSEP corporation under license from Dupont

The Filter Pack is mounted on the V-SEP base unit and contains about 1300 SF, (120m²), of membrane area and is constructed out of high temperature materials. The V-SEP drive system, which vibrates the Filter Pack, is engineered using space age alloys and materials to withstand the

applied stress from a resonating frequency of about 50 Hz. Each base unit is fully stress tested and the factory prior to shipment. The V-SEP drive system is made up of the Seismic Mass, Torsion Spring, Eccentric Bearing, and Lower Pressure Plate.

Project Economics

The table below shows the operating costs for the installation of one V-SEP module as currently configured. The V-SEP is uniquely energy efficient. It comes with a 20 HP drive motor and a 10 HP Pump Motor. Operators interface and maintenance is limited to starting and stopping the unit and a periodical cleaning of the membrane after an extended run. The membrane replacement is the largest operating cost and it is estimated that the life of each module is approximately 2 years. Operator care can improve the life and additional savings could be yielded if the Filter Pack lasts more than 2 years.

V-SEP Operating Costs

Description	Description
V-SEP System Power Consumption*	\$ 7,180
System Maintenance & Cleaning	\$ 8,640
Annual Production (at 20 gfd)	10,500,000 gal/yr

*based on 0.05 \$/kWh electricity cost

V-SEP ... A New Standard in Rapid Separation



Case Study

Installed V \diamond SEP Mining Applications

Acid Mine Drainage
Phosphate Fertilizer
Radioactive Nuclei Removal
Mixed Metals Removal from wastewater
Arsenic Removal
Titanium Dioxide Concentration
Calcium Carbonate Dewatering
Kaolin Clay Concentration
Bentonite Clay
Railcar Washwater
Product Recovery from Wastewater

For more information, contact:

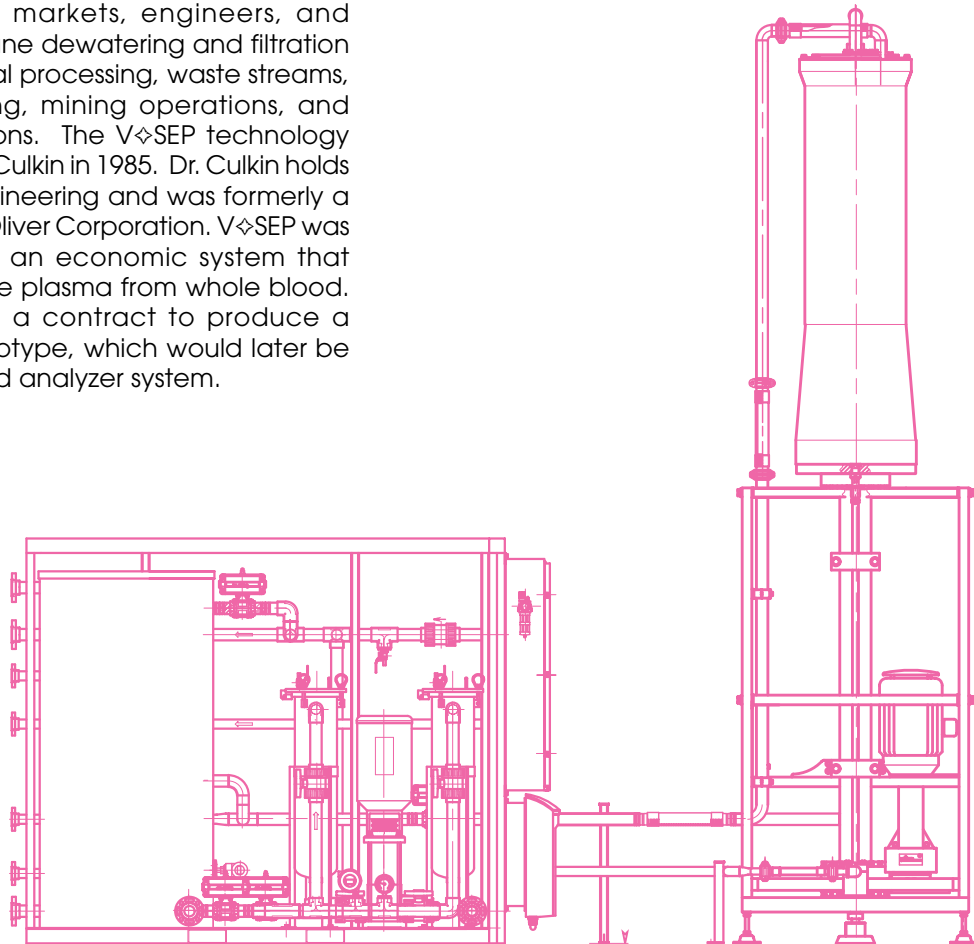
New Logic Research
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info@vsep.com
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Company Profile

New Logic is a privately held corporation located in Emeryville, CA approximately 10 miles from San Francisco. New Logic markets, engineers, and manufactures a membrane dewatering and filtration systems used for chemical processing, waste streams, pulp & paper processing, mining operations, and drinking water applications. The V \diamond SEP technology was invented by Dr. Brad Culkin in 1985. Dr. Culkin holds a Ph. D. in Chemical Engineering and was formerly a senior scientist with Dorr-Oliver Corporation. V \diamond SEP was originally developed as an economic system that would efficiently separate plasma from whole blood. The company received a contract to produce a membrane filtration prototype, which would later be incorporated into a blood analyzer system.

CE



V \diamond SEP ... A New Standard in Rapid Separation

Copper Mining Glossary

Anode - fire-refined copper cast at the smelter into slabs weighing 600 to 1200 pounds of about 99.5% purity; shipped to an electrolytic refinery for final purification.

Ball mill - a rotating horizontal steel cylinder loaded with steel balls which grind the ore to a fine powder consistency.

Beneficiation - concentrating the copper content of the ore; the crushing, screening and grinding of ore and removal of copper-bearing minerals by a flotation process prior to smelting the copper concentrates.

Cathode - refined from anodes in the electrolytic refinery into plates of 99.99% pure copper; these are shipped to factories to be melted and cast into shapes ready for rolling, drawing, or extruding into finished products.

Concentrate - copper-bearing material from the flotation process; contains 15% to 30% copper plus various quantities of sulfur, iron and other impurities.

Electrowinning - electrolytic winning process, wherein copper from copper sulfate (leach) solution is electroplated onto cathodes, ready for market.

Flotation - the process of mixing powdered ore with water and chemical reagents to separate the metallic particles from the waste rock; the metallic particles are collected and dried and this concentrate is sent to the smelter for fire refining.

Gangue - undesired minerals associated with ore; that portion of the ore rejected as tailing in the flotation process.

Leaching - a process of using a weak sulfuric acid solution to dissolve copper from low-grade oxide ores; may take place in vats, heaps, dumps or in situ (in place).

Matte - a mixture of sulfur, iron, and copper, containing approximately 20% to 45% copper, tapped from reverberatory furnace in the smelter.

Mill - the facility containing rod mills (if used), ball mills, and flotation cells where the ore is ground and copper concentrate extracted. Also called the concentrator.

Open pit mining - A surface mining method in which overlying rock and soil are removed to expose the ore body, which is then drilled, blasted and loaded into trucks or railroad cars for haulage from the pit.

Ore - rock containing enough mineral value to warrant the expense of mining it.

Slag - waste rock from the smelter. The black lava-like material is primarily iron and silica.

Smelter - the plant in which fire refining takes place.

Sulfide ore - ore composed of copper, sulfur, and usually iron along with the various other minerals making up the host rock.

Tailings - the finely ground residue or waste materials contained in the ore remaining after floating off the copper-bearing concentrate.

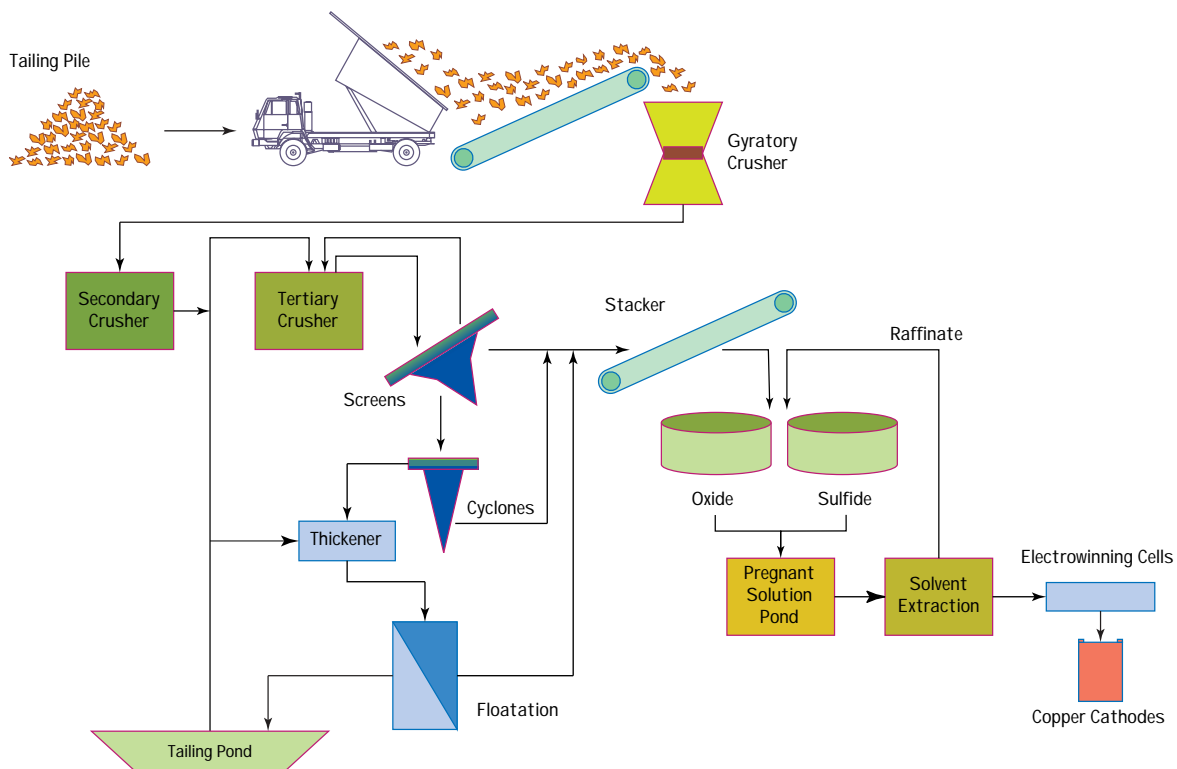


Exhibit R:

October 17, 2008 e-mail from Cindy Skrukrud

----- Original Message -----

From: [Cindy Skrukud](mailto:Cindy.Skrukrud)

To: kurt.neibergall@illinois.gov

Cc: [Traci Barkley](mailto:Traci.Barkley) ; [Albert Ettinger](mailto:Albert.Ettinger) ; becki.clayborn@sierraclub.org ; james.gignac@sierraclub.org ; [Joyce Blumenshine](mailto:Joyce.Blumenshine) ; [Cindy Skrukud](mailto:Cindy.Skrukrud)

Sent: Friday, October 17, 2008 7:56 PM

Subject: Additional materials from Sierra Club for NPDES IL0078727, Hillsboro Energy Deer Run Mine

Dear Kurt,

Because of our concerns about preventing pollution of downstream waters which support sensitive aquatic life and serve as drinking water sources from toxic constituents found in coal (such as the bioaccumulative selenium for which USEPA's Current National Recommended Water Quality Criterion (chronic) is 5 ug/L; whereas Illinois' current water quality standard is 1 mg/L, 2000 times higher and heavy metals like cadmium, lead and zinc.), we believe it is important that the levels of such pollutants in the runoff from Deer Run be anticipated and minimized. I wish to place the following documents into the hearing record as they provide information on the levels of such toxics in Illinois coal, specifically for the Herrin No. 6 coal seam planned to be mined at Deer Run mine.

[Resource Assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin](#)

J.R. Hatch, R.H. Affolter U.S. Geological Survey Professional Paper 1625-D Version 1.0, 2002 available at <http://pubs.usgs.gov/pp/p1625d/>

[Trace Elements in Coal: Occurrence and Distribution.](#)

Circular 499 1977. 154p. Illinois State Geological Survey

[Mineral Matter and Trace Elements in the Herrin and Springfield Coals, Illinois Basin Coal Field.](#)

C/G 1983-4 EPA-600/7-84-036. **1983.** 162p.

The latter two are both available at <http://www.isgs.uiuc.edu/maps-data-pub/publications/coal-pubs/quality.shtml>

Thank you for the opportunity to submit this additional information.

Sincerely,

Cindy Skrukud
Clean Water Advocate
Sierra Club, IL Chapter
70 E Lake St. Suite 1500
Chicago, IL 60601

Exhibit S:

VSEP Treatment of RO Reject from Brackish Well Water

Technical Article

VSEP Treatment of RO Reject from Brackish Well Water

A Comparison of Conventional Treatment Methods and VSEP, a Vibrating Membrane Filtration System.

Greg Johnson^a, Larry Stowell^a, Michele Monroe^a

^aNew Logic Research, Incorporated
1295 67th Street, Emeryville, CA 94608

Presented : 2006 El Paso Desalination Conference, El Paso Texas March 15th - 17th, 2006

Keywords: Membrane, Fouling, Mineral Scale, Solubility Limits, Scaling Control, Reverse Osmosis, Filtration

Abstract

Conventional spiral wound membrane systems using reverse osmosis or nano-filtration membranes are increasingly being used to treat well water from underground sources to supplement local drinking water supplies. Many of the remaining underground water sources are "Brackish" water sources where the dissolved solids can be 5,000 mg/L or even higher. One of the difficult engineering aspects of conventional spiral membrane technology is the treatment of the residual concentrated brine left over from the process. New Logic Research, Emeryville California, has developed and manufactures a new proprietary vibrating membrane filtration system that is not limited by solubility of sparingly soluble salts and is capable of extremely high recoveries of treated water from brine. The use of a vibrating membrane mechanism to avoid membrane colloidal fouling is new and is just the kind of improvement needed to increase the yield of filtered water from brackish well water.

The Vibratory Shear Enhanced Process, (VSEP), technology has been installed in other areas for treatment of surface water to make ultrapure water for manufacturing and has also been used in manufacturing plants to treat the wastewater reject from other membrane systems to assist in Zero-Discharge. Recent pilot trials have been conducted using the VSEP technology to examine its use in brackish well water filtration and to volume reduce reject from other spiral membrane systems. This approach would extend the use of the VSEP technology to the municipal drinking water market in addition to the chemical processing and manufacturing markets where the technology has been used for many years. This article will discuss the recent VSEP pilot trial results and then make comparisons between using VSEP and other methods of brine reject disposal currently being employed or considered.

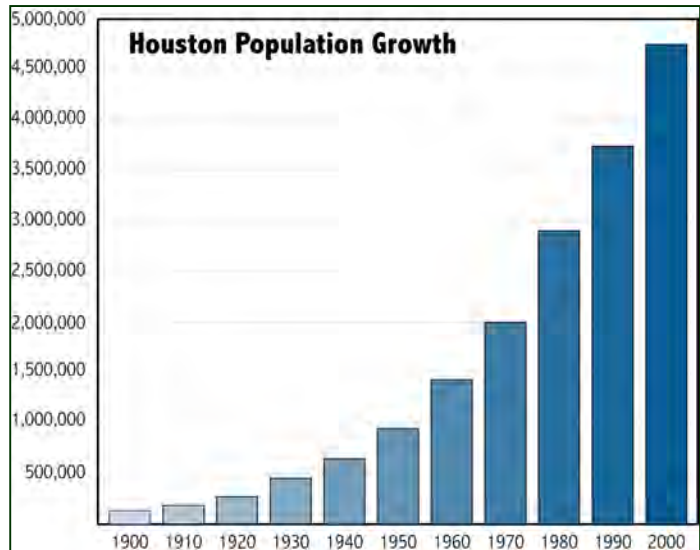
Water Supply Background

With populations rising and water sources becoming stretched, increasing attention is being paid on how water is used and reused. Industry, agriculture, and domestic water users are all competing for this most precious natural resource. Many in the Southwestern United States are seeing dramatic population growth rates, while population levels in the North and Northeast are remaining fairly stable. The problem is that populations are increasing in areas of the country with the most limited water supplies. For example, the U.S. Census Bureau [7] estimates that the population of Arizona will double within the next 25 years.

Clearly, the case for retrofits and additional capacity has been made. The EPA's Office of Water recently estimated the capital required over the next 20 years for both water and wastewater upgrades is nearly \$500 Billion USD (EPA, The Clean Water and Drinking Water Gap Analysis, 2002). These estimates are not adjusted for inflation and use current value terms. The EPA attributes these costs to retrofitting treatment plants and infrastructure that are obsolete, more stringent drinking water and wastewater standards, and increasing expense and controversy associated with capital improvement projects.

During the 1970s and 1980s, the EPA provided more than 60 Billion Dollars for construction of public wastewater treatment projects through its Construction Grants Program. [1] The Clean Water Act (CWA) of 1987 changed the Construction Grants Program and through an amendment to the CWA, the grant program was terminated in 1990. Under the new procedure, the EPA initiated the State Revolving Fund (SRF). Through the SRF, the EPA provides capitalization seed money to the states, which in turn offer low interest loans to local communities for municipal projects. The net effect is that although local municipal districts receive low cost loans, they now must pay for 100% of capital improvement projects. Under the Construction Grants Program, the EPA paid about one-half of these costs directly.

Now that local water utility companies are responsible for 100% of the cost of capital projects, the construction of large mega projects such as Dams and large aqueducts will be greatly curtailed. Faced with aging infrastructure and limited current capacity, Municipal water districts are working on ways to optimize existing systems and supplement conventional sources of drinking water using relatively small capital projects. [3] Increasingly, well water is being used as a source of raw water for distribution to the Municipal water market. These relatively small capital projects can be implemented quickly to supplement water supplies and the cost of these projects is more in line with what local water districts are able to manage.



Texas Desalination Plants

There are currently approximately 100 brackish water desalination plants in Texas. Most use brackish well water, but about one in six uses brackish surface water. There are no seawater desalination plants currently in Texas. The current output of treated water of these plants totals about 39.6 MGD. From this effort, a waste stream of 10.5 MGD is produced that must be disposed of. Even though it is a large amount, this is much smaller than the total amount of Produced Water from Oil drilling already disposed of each day in Texas. [10]

Well Water Treatment

Most well water and surface waters contain varying amounts of suspended solids, including silt, clay, bacteria, and viruses. In addition, they may contain many harmful dissolved solids such as Arsenic. It is necessary to remove these prior to distribution to the domestic or industrial consumer. Suspended solids not only affect the aesthetic acceptability of the water; they also interfere with the conventional disinfecting process using chlorine. The principal treatment processes used to remove suspended solids are sedimentation and filtration. In the case of brackish waters containing large amounts of dissolved solids, membrane filtration must be used. In many plants that treat surface or well waters, there is a pre-sedimentation reservoir ahead of the treatment units. The reservoir allows the larger particles to settle as well as to provides a volume buffer against changes in water quality.

Rapid sand filters or mixed media filters are used next as pre-treatment to conventional spiral membrane systems. These can remove the larger suspended solids but cannot remove appreciable quantities of colloidal or sub-micron sized particles without chemical pre-treatment. While these can act as an initial filter, the effluent from media filters can be as colored or turbid as the incoming water. After media filtration, some chemical pretreatment is generally done to optimize the spiral membrane system. Finally, a reverse osmosis membrane system is used to filter the water and provide clean water suitable for drinking water supplies. Often, this water is blended with other fresh water sources to achieve an acceptable taste.

Water Standards

Drinking water is monitored to conform to acceptable levels of many harmful chemicals and organisms. Setting of standards is a continual process as more is learned about the potential harmful effects of various constituents. In addition to monitoring for health risks, water quality is controlled for aesthetic and operational purposes. For example water high in sulfate levels while not toxic can have a laxative effect. Water high in iron can lead to hardness and staining in laundering. Water high in organics can have a foul taste. Recent fatalities involving toxic microorganisms have renewed a review of the standards when it comes to monitoring and treatment to prevent harmful bacteria from entering the distribution network. The following list summarizes some of the targeted undesirable ingredients to drinking water.

Arsenic - Arsenic is present at very low levels in all surface waters. It is a naturally occurring chemical found in mineral deposits and will go through a natural dissolution process bleeding it into waterways. Arsenic is a carcinogen and must be controlled in drinking water sources.

Chromium - Trivalent Chromium is the naturally occurring state of Chromium and is not considered toxic. However, naturally occurring Chromium can be oxidized in raw water to form the more toxic Hexavalent Chromium. Other sources of Hexavalent Chromium are from paint and plating wastewater that can contaminate waterways.

Cyanide - The human body detoxifies small amounts of Cyanide. Lethal toxic effects can occur if the levels are above certain limits and the detoxification mechanism is overwhelmed. Chlorination is normally sufficient to oxidize Cyanide and reduce it to appropriately low levels.

EPA Standards for Health	
Total Organic Carbon	5.0 mg/L
Arsenic	0.010 mg/L
Barium	2.0 mg/L
Cadmium	0.005 mg/L
Chromium	0.1 mg/L
Cyanide	0.2 mg/L
Fluoride	2.0 mg/L
Lead	0.015 mg/L
Mercury	0.001 mg/L
Selenium	0.05 mg/L
Uranium	0.1 mg/L
Vinyl Chloride	0.002 mg/L

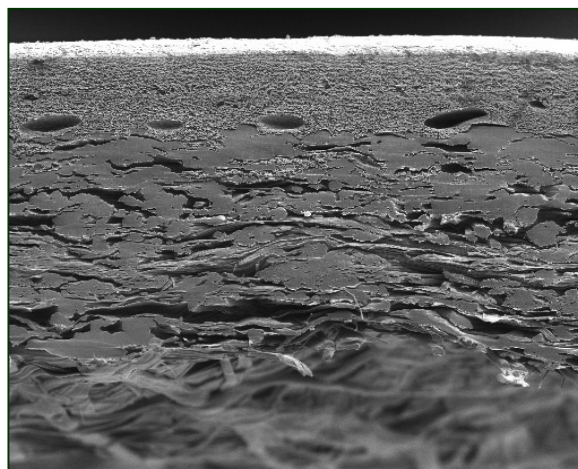
Selenium - Selenium is an essential trace element for human consumption. The exact toxic effects of it are not known and its interaction in the human body is very complex. In order to provide safety factor, levels of Selenium are controlled in drinking water so that over-exposure to Selenium does not occur.

Uranium - The naturally occurring form of Uranium is as the Uranyl Ion UO_2^{++} . Uranium, while it may be radioactive, is actually more serious as a toxin to the kidney. At high enough levels, it can cause permanent kidney damage.

Membrane Filtration of Drinking Water

The first sand filter used for clarifying drinking water was installed in Paisley Scotland in 1804. Since then some advances have been made in sand filter design and in the use of coagulation prior to filtration. However, the basic concept has remained the same for nearly 200 years. There has been a trend in recent years towards the use of polymer membranes for treatment of potable water for domestic and industrial use. Significant advances in polymer chemistry within the last 20 years and the use of membranes is becoming more widely accepted. In addition to the membrane itself, significant advances have occurred with respect to the delivery system. New technologies are appearing all the time and membrane systems now offer an effective competitive treatment method option.

There are four basic types of membranes based on pore size or rejection characteristics. Microfiltration (MF) is the most open media with pore sizes from 0.1 micron and larger. Ultrafiltration (UF) membranes have pores ranging in size from 0.005 micron to 0.1 micron. These are typically rated according to the minimum nominal molecular weight size that the membrane will reject. This range for UF membranes is from 2,000 MWCO (molecular weight cut off) to 250,000 MWCO. Nanofiltration (NF) and Reverse Osmosis (RO) membranes don't have pores as such and work by diffusion. Ionic charge and size play a role in the permeation through the membrane. Monovalent ions will pass more freely than multivalent or divalent ions. NF membranes are designed to target multi-valents ions where as RO will remove monovalent ions.



0.1 µm Teflon MF Membrane

For the purpose of non-brackish water filtration, Microfiltration is generally good enough. There is a correlation between pore size and throughput. Generally, the larger the pore, the higher the flow rate through a given area of membrane. Since filtration of brackish water requires removal of silt, suspended particles, bacteria, and other microorganisms, a Microfilter is normally used. This type of filter will provide the highest throughput and best economics for a given flow rate. If the water source is especially colored or turbid or if taste complaints are a problem, Ultrafiltration can be used which is tighter than Microfiltration. UF membranes can remove very small organic matter, humic substances, and even viruses. UF membranes can improve color, taste, and odor of the drinking water. [6]

In the case of commercial bottled water or brackish water filtration, tighter membranes including Nano-filtration and Reverse Osmosis are used. In the case of brackish water, MF or UF would not reduce the high levels of dissolved solids and could not provide filtrate meeting the primary drinking water standards. Brackish water is a term that covers a very broad range of water quality. Brackish water can have anywhere from 1000 ppm to 10,000 ppm of TDS. Above 10,000 ppm is considered Saline Water. The most appropriate membrane for brackish water still depends on the concentration of TDS. For slightly brackish waters, (1,000 to 3,000 ppm), nano-filtration would probably yield an acceptable water quality. For high level brackish water, (>3,000 ppm), reverse osmosis is probably needed as in the case of seawater desalination.

Membrane Technology

Advanced treatment utilizing membranes for drinking water is becoming more popular. Although their use in generating drinking water has a long history, improvements in membranes lead to increasing acceptance and better overall economics. Membranes are uniquely capable of precise control of contaminant levels. NF and RO can be used to remove varying degrees of dissolved solids meeting the strict drinking water guidelines.

Most membranes used today are made of polymeric materials including: polyamide, polysulfone, regenerated cellulose, kynar (PVDF) and Teflon® (PTFE). The pores on most polymer membranes are so small they cannot be seen even with a scanning electron microscope. The pore sizes are determined by how well the membrane rejects particles of a known size. The membrane itself allows water to pass through the physical pores or through the matrix of the polymer and does not allow larger molecules or suspended solids to pass. Selection of the proper membrane depends on the separation required. [5]

Limitations of Conventional Membranes

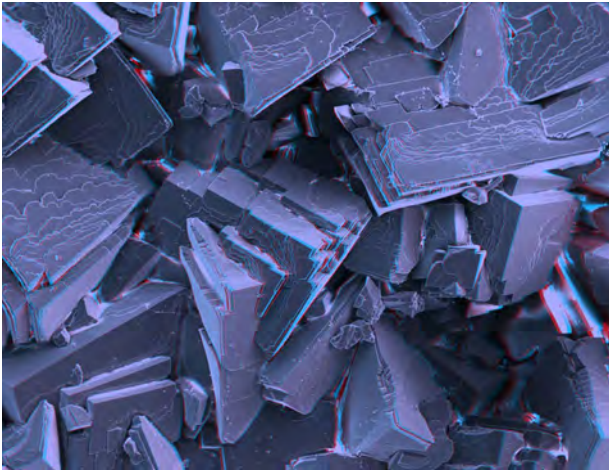
Membrane fouling and scaling can significantly increase the cost of a membrane system as well as reduce its reliability. As a result fouling, elaborate pre-treatment is used ahead of most membrane systems and the solubility limits of various constituents are monitored. The concentration of these constituents is controlled so that the solubility limit is not exceeded causing precipitation of colloidal materials and mineral scaling of the system. The net effect is that the % recovery of filtered water will be limited by the solubility of sparingly soluble salts and Silica. This limitation has been the cause of a great deal of recent development in membrane science. Several approaches have been used to try and minimize the effects of fouling. Polymer chemists are developing many new membranes that have “low fouling” characteristics. Several techniques are used like altering the Zeta Potential or amount of ionic charge of the membrane surface. Another method is modifying the thermodynamic potential of the membrane surface by using low surface energy materials. These materials reduce the chemical free energy change upon absorption of foulants.

Other developments have focused upon offering the potential foulants an alternate site for chemical attraction, or limiting their rate of precipitation. These methods ensure foulants are used up or diluted in their effect and thus will not pose a threat to the membrane itself. Examples of these are “anti-scalants” which can be organic compounds with sulfonate, phosphonate, or carboxylic acid functional groups. Chelating agents are also used which sequester and neutralize a particular foulant, especially metals. Carbon, Alum, and zeolites can be used as an additive. These offer huge surface areas loaded with nucleation sites suitable for absorption or crystallization to occur spontaneously at relatively low solubility levels.

Most often, the optimum membrane system will employ several of these techniques in order to combat or avoid fouling. For example, crossflow membrane systems will utilize pre-treatment of the feed water by using a 5.0µm bag filter followed by a 1.0µm Cartridge filter. Then the system will use a “Low Fouling” membrane with advantageous surface chemistry. An antiscalant will be dosed into the feed to sequester any potential foulants. And finally, aggressive crossflow is used to keep the membrane clear. This is a suitable treatment process as long as the feedwater is within specific criteria including: LSI (Langolier Saturation Index), SDI (Silt Density Index), and concentrations of sparingly soluble salts and other suspended colloids. [6]

Sparingly Soluble Salts

Even with all of these tools, the recovery of these systems can be limited to low levels. This results in a large volume of rejected brine that must be further treated or disposed. Minerals that will precipitate and foul conventional membrane systems as they come out of solution are predominantly composed of divalent metal ions. Monovalent metals such as Sodium and Potassium are nearly completely soluble, whereas, in the presence of Sulfate, Phosphate, or Carbonate, divalent ions such as Calcium, Iron, Magnesium, Barium, Strontium, Radium, Beryllium, Lead, and Silicon are nearly insoluble. [8]



Calcium Carbonate Crystals

When pressure is applied and reverse osmosis filtration occurs, nearly pure water is forced through the membrane thus changing the equilibrium and consequently the concentration of solutes to solvent. If this process continues until the solute reaches its limit of solubility, precipitation is likely to occur. Once precipitation has begun at appropriate nucleation sites then as more water is removed more precipitated materials are created. This will continue, as the system will attempt to keep the concentration of solutes at or below the solubility limit. If water is removed by filtration, but not in enough quantity to reach the solubility limit of the solutes, no scaling or precipitation will occur. One primary method used during conventional membrane filtration is recover water from the system to the point where solubility limits are not reached. The second method is to use anti-scalants that

either inhibit the growth of crystals or sequester the reagents and thus reduce the available concentration. Software programs have been created to calculate the solubility limits based on known feed values. Once you enter the feed values, the program will calculate solubility and then instruct the user on the highest acceptable recovery value for sustainable system operation.

Common Forms of Mineral Scales	
Calcium Carbonate	Calcium Sulfate
Calcium Phosphate	Barium Sulfate
Strontium Sulfate	Iron Hydroxide
Silicon Dioxide (Silica)	

Calculating % Recovery & Solubility Limits

Conventional membrane systems have strict guidelines for incoming feed water composition. The reason for this is to minimize the potential problem of scaling or precipitating of slightly soluble ions. Precipitated insoluble materials like mineral scale can foul or blind off crossflow membranes quickly. These must be controlled in order to operate the system properly. Levels of reagents are measured to insure that they will remain soluble during the filtration process. These limits can be exceeded to some degree if antiscalants are used to consume reagents or to inhibit and block growth of scale.

For example:

Well Water is to be treated using membranes for purification. The water contains 30 ppm of dissolved silica (SiO₂). The solubility limit of Silica can be 120 ppm depending on pH and temperature. To figure how much pure water can be extracted through filtration before the solubility limit of silica is reached the following equations can be used:

$$120 \text{ ppm (Ksp)} \div 30 \text{ ppm} = 4$$

The Silica can be volume reduced by a factor of 4 before the solubility limit will be reached.

$$100\% \div 4 = 25\%$$

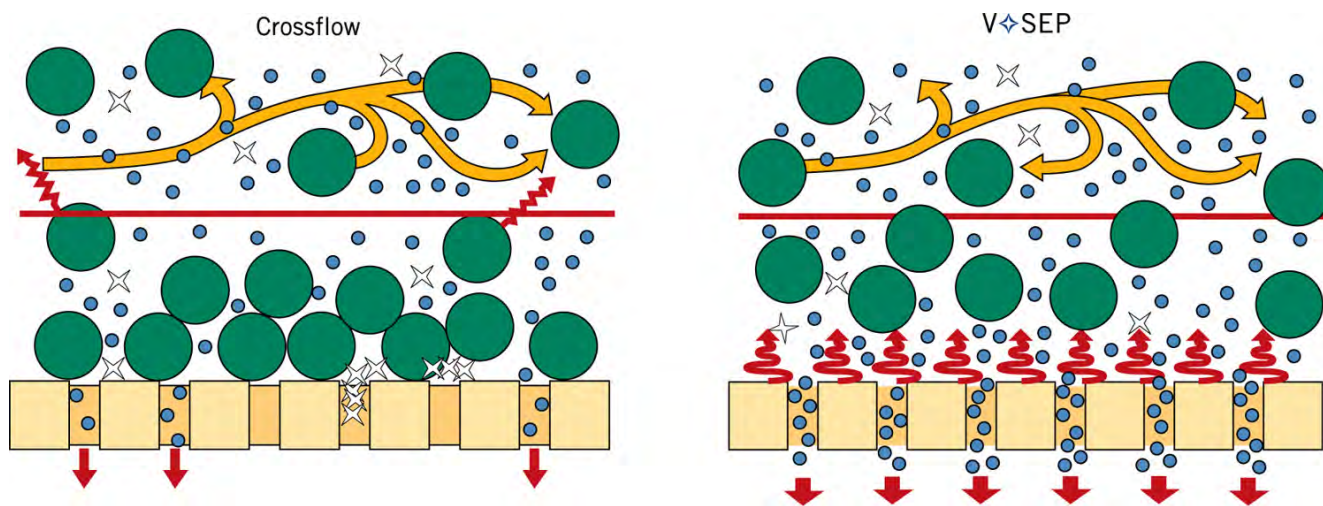
The liquid volume can be reduced by 75% so that a concentrate volume of 25% is left at which point the solubility limit has been reached. This is also known as a 75% recovery. Since near the solubility limit, there is a metastable region where precipitation can occur prior to the solubility limit if favorable conditions exist some safety factor must be used. Slight variations in temperature, pressure, and pH can shift the point of solubility and cause unexpected scaling. For this reason, conventional membrane systems are not run at the solubility limit, rather they are run at significantly less than that or anti-scalants are used to insure adequate safety factor.

In the example above, with 30 ppm of Silica, safe operation for conventional membrane systems would be at 50% recovery without pretreatment or 75% recovery with antiscalant addition. If the silica content of the raw water was 100 ppm, the water is almost not treatable using conventional membranes alone. Water softening must be used to reduce the hardness and mineral content to sufficiently low levels prior to entry into the membrane system.

When scaling occurs in a membrane system, colloids of insoluble mineral salts are formed. While some scaling can occur on the membrane itself, most of it will occur at other more efficient locations and then will become suspended colloids, which will act as any other suspended solid during the filtration process. Conventional membranes are subject to colloidal fouling as suspended matter can become polarized at the membrane surface and obstruct filtration. Crossflow is used to reduce the effects of concentration polarization. The main problem with scaling for membrane systems is that the process introduces a large amount of potential foulants into the system, which can reduce flux. Just as conventional membranes have limits on TDS due to the solubility limits of the various constituents, they also have limits on TSS, as colloidal fouling will occur if these levels are too high.

V◇SEP Advantages

V◇SEP employs torsional vibration of the membrane surface, which creates high shear energy at the surface of the membrane. The result is that colloidal fouling and polarization of the membrane due to concentration of rejected materials are greatly reduced. Since colloidal fouling is avoided due to the vibration, the use of pretreatment to prevent scale formation is not required. In addition, the throughput rates of V◇SEP are 5-15 times higher in terms of GFD (gallons per square foot per day) when compared to other types of membrane systems. The sinusoidal shear waves propagating from the membrane surface act to hold suspended particles above the membrane surface allowing free transport of the liquid media through the membrane. [9]

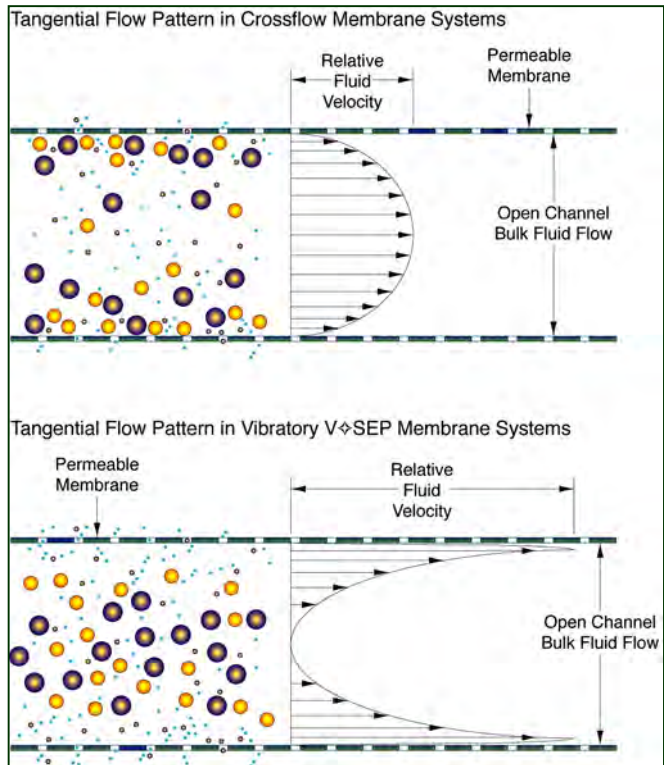


Fluid Dynamics Comparison between VSEP and Conventional Crossflow Filtration

The V \diamond SEP membrane system is a vertical plate and frame type of construction where membrane leafs are stacked by the hundreds on top of each other. The result of this is that the horizontal footprint of the unit is very small. As much as 2000 square feet (185 m²) of membrane is contained in one V \diamond SEP module with a footprint of only 4' x 4'.

VSEP employs torsional oscillation at a rate of 50 Hz at the membrane surface to inhibit diffusion polarization of suspended colloids. This is a very effective method of colloid repulsion as sinusoidal shear waves from the membrane surface help to repel oncoming particles. The result is that suspended solids are held in suspension hovering above the membrane as a parallel layer where they can be washed away by gentle tangential crossflow.

This washing away process occurs at equilibrium. Pressure and filtration rate will determine the thickness and mass of the suspended layer. Particles of suspended colloids will be washed away by crossflow and at the same time new particles will arrive. The removal and arrival rate will be different at first until parity is reached and the system is at a state of equilibrium with respect to the diffusion layer. (Also known as a boundary layer) This layer is permeable and is not attached to the membrane but is actually suspended above it. In VSEP, this layer acts as a nucleation site for mineral scaling. Beneath the hovering suspended solids, water has clear access to the membrane surface.



Mineral scale that precipitates will act in just the same way as any other arriving colloid. If too many of the scale colloids are formed, more will be removed to maintain the equilibrium of the diffusion layer. As documented by other studies, VSEP is not limited when it comes to TSS concentrations as conventional membrane systems are. Conventional membrane systems could develop cakes of colloids that would grow large enough to completely blind the conventional membrane. In VSEP, no matter how many colloids arrive at the membrane surface there are an equal number removed as the diffusion layer is limited in size and cannot grow large enough to blind the system. In fact VSEP is capable of filtration of any liquid solution as long as it remains a liquid. At a certain point, as water or solvent is removed, the solution will reach a gel point. This is the concentration limitation of VSEP.

In the VSEP membrane system, scaling will occur in the bulk liquid and become just another suspended colloid. One other significant advantage is that the vibration and oscillation of the membrane surface itself inhibits crystal formation. The lateral displacement of the membrane helps to lower the available surface energy for nucleation. Free energy is available at perturbations and non-uniform features of liquid/solid interfaces. With the movement of the membrane back and forth at a speed of 50 times per second, any valleys, peaks, ridges, or other micro imperfections become more uniform and less prominent. The smoother and more uniform a surface, the less free energy is available for crystallization. In the absence of any other nucleation sites, this would lead to a super-saturated solution. In actual fact, what happens is that nucleation occurs first and primarily at other nucleation sites not being on the membrane, which present much more favorable conditions for nucleation.

Crystals and scale also take time to form. The moving target of the membrane surface does not allow sufficient time for proper germination and development. The solids in the bulk fluid present a much more favorable nucleation site. Whereas, with conventional static membranes, scale formation on the membrane is possible and has plenty of time to develop and grow. Another feature of VSEP is that filtration occurs at a dramatically higher rate per m² than with conventional membranes due to the suspension of colloids above the membrane. Studies have shown as much as a 15 times improvement in flux per area. The result of this is that as much as 1/15th of the membrane area is required to do the same job as a conventional crossflow membrane. This is beneficial for many reasons one of which is hold-up volume of feed waters.

The result is that filtration occurs quickly and the length of travel of feed waters over membrane surfaces is reduced by as much as 15 times. This means that there is much less time for scaling and crystal formation within the membrane system. Crystal formation is a function of time, especially with respect to Silica, which is very slow to grow. If scaling is to occur within the system, it will more likely occur at high-energy nucleation points and not on the membrane. In addition to that, the high filtration rate is capable of making a super saturated solution, which may not even have residence time sufficient to react within the membrane system itself and may wait until it has been discharge to complete the equilibrium process.

Since VSEP is not limited by solubility of minerals or by the presence of suspended colloids, it can actually be used as a crystallizer or brine concentrator and is capable of very high recoveries of filtrate. The only limitation faced by VSEP is the osmotic pressure once dissolved ions reach very high levels. Osmotic pressure is what will determine the recovery possible with a VSEP system.

Validation Testing

New Logic has pilot tested several projects where the objective was to volume reduce reject from a spiral RO membrane system. This section will illustrate the performance of pilot tests conducted recently all pertaining to high TDS brine concentration.

The first example is not a case of spiral reject, rather it is a case of VSEP treating saline water from an oil production well known as produced water. This test case illustrates the capabilities of the VSEP system. New Logic conducted onsite pilot trials for several months at an oil production site in Central California. The objective was to treat the water from the oil production wells using reverse osmosis so that the treated water could be re-injected into the drinking water aquifer for pressure stabilization.

The results with respect to the primary objective of generating permeate of a quality that reaches the goals for re-injections to the aquifer were met. The water treated was very high in Chlorides and because of the very low limits for discharge, two stages of RO filtration were required. In this case, VSEP RO was used as a primary stage with the RO filtrate being polished in a 2nd stage using a conventional Spiral RO system. The following table shows the analytical results from this test work.

Component:	Chloride	Sulfate	Nitrate	TDS	Boron	Sodium
Initial Feed	3285 mg/L	304 mg/L	4 mg/L	7314 mg/L	23.4 mg/L	2900 mg/L
VSEP Permeate	628 mg/L	25 mg/L	0 mg/L	1617 mg/L	5.4 mg/L	614 mg/L
Spiral Permeate	11 mg/L	0 mg/L	0 mg/L	51 mg/L	0.39 mg/L	25 mg/L
Discharge Limit	127 mg/L	127 mg/L	4.3 mg/L	510 mg/L	0.64 mg/L	85 mg/L

This test illustrates the ability of VSEP to treat water that is very high in TDS and in other scale forming components. In fact, in this case, Silica, Carbonates, and Sulfates were at saturation with respect to solubility.

VSEP for Brackish Water Reject from an Existing Spiral System

New Logic conducted recent pilot trials on reject from an existing membrane system installed in Southern California. The primary objective was to treat the reject water to minimize reject from the water plant. The result is that disposal costs would be reduced and the yield of clean water could be increased. The primary objectives were to meet limits for Color, TOC, and other taste related organics. The customer had previously tested other Ultrafiltration membrane systems for treating this reject and the results were poor regarding flux rate and recovery. The purpose of this test was to see how well VSEP could perform as compared to conventional UF membrane systems.

Since VSEP is not limited by solubility and since meeting Primary Drinking water standards would be a benefit, a tight Nano-filtration membrane was used. The filtrate from the existing plant and the VSEP 2nd stage concentrator system would be blended, so the better the quality from the VSEP, the more flexibility there would be when it comes to blending.

After scanning several NF membranes, a 90% NaCl reject NF membrane was chosen for further study. Concentration and Flux vs. Time studies were completed and the results were excellent. During a concentration study, the system was started up first in "Re-circulation" mode and also set to the Optimum Pressure and expected process temperature. The system was run for a few hours to verify that the flux was stable and the system had reached equilibrium.

Then, the permeate line was diverted to a separate container so the system is in "Batch" mode. The permeate flow rate was measured at timed intervals to determine flow rate produced by the system at various levels of concentration. The following Table shows the performance during the "Concentration Study":



VSEP Onsite Pilot Trials in California

Ave Flux	Initial Flux	Ending Flux	Pressure	Initial Solids	Ending Solids	% Recovery
65.2 gfd	144.5 gfd	11.47 gfd	450 psi	0.3 %	11.8 %	98.8 %

Based on the Data, the NF Membrane was found to be suitable because it provided a high, stable permeate flux with no solids or color in the permeate. It also met the process objectives for % recovery and demonstrated good performance over time. In this case, the maximum % recovery achieved was 98.8 %, which yielded an average flux of 65.2 gfd. (gallons/sq ft/day)

The following table shows the final results of testing:

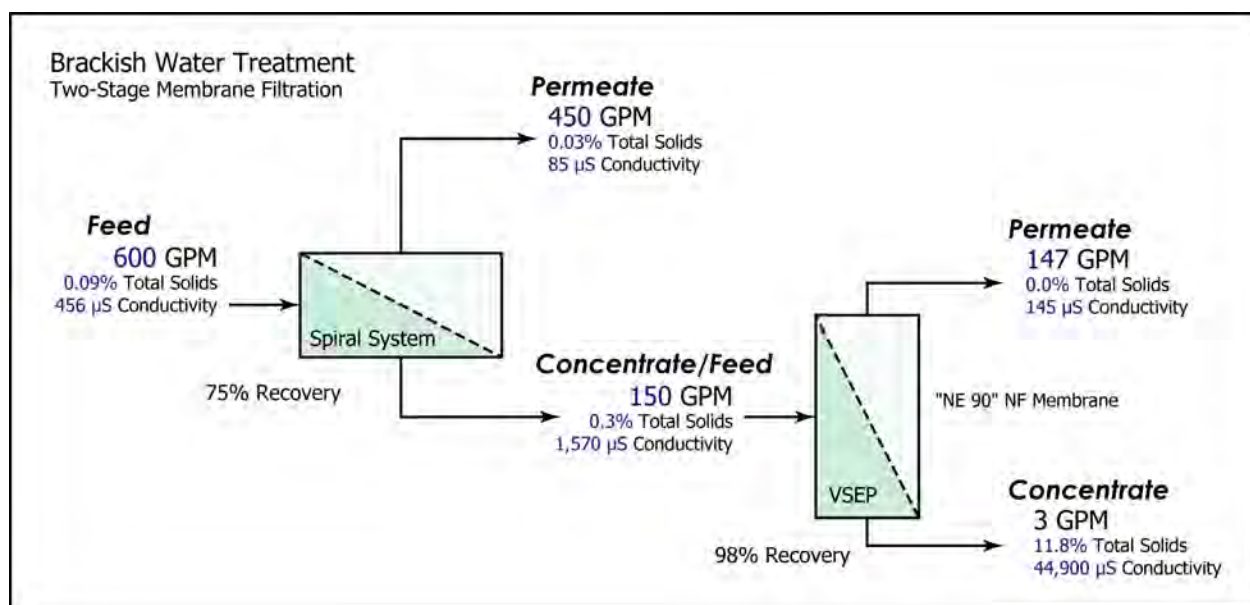
Membrane	% Total Solids	Conductivity	pH	Volume
Initial Feed	0.3 %	1,570 μ S	8.68	100 %
Final Permeate	0.0 %	145.4 μ S	8.98	98.8 %
Final Concentrate	11.8 %	44,900 μ S	9.35	1.2 %

The results exceeded expectations as the VSEP was able to produce greater than 98% recovery of treated water. In addition, the customer had previously tested other UF membrane systems that had flux rates of about 20 gfd. VSEP, using a much tighter NF membrane, was able to achieve a very high flux rate of 65 gfd (gal/sq ft/day).

The following table shows the complete analytical results from grab samples collected during the pilot trails. The purpose of testing was to confirm compliance with Primary and Secondary EPA drinking water standards related to health issues and aesthetic considerations.

RO Reject VSEP Analytical Results			VSEP	VSEP	VSEP	Reporting
Analyte		EPA Limit	Feed	Permeate	Reject	Limit
Aluminum	Al	0.050 mg/L	0.600	ND	27.550	0.100
Arsenic	As	0.010 mg/L	0.008	ND	0.253	0.005
Barium	Ba	2.000 mg/L	0.120	ND	5.706	0.010
Cadmium	Cd	0.005 mg/L	ND	ND	-	0.005
Calcium	Ca	none	45.00	ND	2,235.0	0.500
Chromium	Cr	0.100 mg/L	0.038	ND	1.557	0.010
Copper	Cu	1.000 mg/L	0.029	ND	1.107	0.010
Iron	Fe	0.300 mg/L	2.300	ND	112.55	0.100
Lead	Pb	0.015 mg/L	ND	ND	-	0.003
Magnesium	Mg	none	3.200	ND	147.75	0.500
Selenium	Se	0.050 mg/L	0.008	ND	0.302	0.005
Silver	Ag	0.100 mg/L	ND	ND	-	0.005
Zinc	Zn	5.000 mg/L	0.180	ND	8.510	0.020
Cyanide	CN	0.200 mg/L	ND	ND	-	0.010
Silica	SiO ₂	none	23.00	5.300	890.3	1.000
Chloride	Cl	250 mg/L	50.00	8.300	2,093.3	0.200
Fluoride	F	2.000 mg/L	1.500	0.200	65.20	0.100
Sulfate	SO ₄	250 mg/L	120.0	1.800	5,911.8	0.500
Total Dissolved Solids	TDS	500 mg/L	2,340	82.0	112,982	10.0
Color		15 color units	13,000	ND	-	5.0

By using VSEP to treat the current reject from the installed NF system, this client will be able to achieve 99% recovery of treated water, leaving only 1% of the volume to be disposed of as reject. The following is a process schematic of the final system design.



Other VSEP Water Installations

V◇SEP Treats River Water

New Logic installed its Vibratory Shear Enhanced Processing (V◇SEP) in July, 1997 at a major international electronic disk manufacturing facility at Hokkaido Island in Northern Japan. The V◇SEP system is used for treatment of river water for ultra-pure water production at this facility. The V◇SEP system uses an ultrafiltration membrane module and is able to treat river water in order to remove or reduce humic substances, color, turbidity, permanganate consumption and total iron to below the required limits. The application of V◇SEP membrane technology to treat river water for ultra-pure water production at electronic disk fabrication facility was found to be an attractive economic alternative to the conventional sand filter water treatment technology. Concentration of the raw river water ranges from 5 to 10 mg/L of TSS. Permeate from the V◇SEP has less than 1 mg/L TSS. VSEP also reduced color from 67 color units to <1 color unit, from 2 NTU turbidity to <0.1 NTU, and from 0.1 mg/L Iron to <0.05 mg/L of total Iron.

Commercial Drinking Water Case Study

New Logic has installed a nearly 1 Million Gallon per day water filtration system for a major bottling company. The filtrate from this system is purified and disinfected using an Ultrafiltration membrane and then sent on to the bottling process where it becomes a consumer product for consumption. In this case, aesthetic improvement was the goal due to a large number of taste complaints. Reduction of TOC causing poor taste has been effectively reduced by the use of a 30,000 mwco UF membrane. One other benefit of the filtration is the near complete removal of all bacteria and other organisms. Normally, Microfiltration could be used with higher throughput per SF of membrane, but in this case TOC reduction required the use of a UF membrane. The previous system design consisted of a Multi-Media filter feeding a Carbon filter. Normal operation involved frequent recharging or disposal of the Carbon media. In addition, the water quality led to numerous taste complaints. The addition of V◇SEP to the process improves taste, reduces TOC, and allows the Carbon filters to run trouble free. New Logic has completed several surface water facility installations using this vibrating membrane system for treatment to produce ultra-pure water. The results have demonstrated many advantages of this new membrane technology when compared to the conventional treatment methods.

Brine Treatment Method Comparisons

There are many methods of treatment currently being used for Brackish Water RO Reject Disposal. Some of these methods include:

- Evaporation Pond
- Deep Well Injection
- Disposal at Sea
- Reclaimed use for Industry or Irrigation
- Blending with POTW Discharge
- Advanced Thermal Evaporation Methods

The treatment method selected will vary depending on the site conditions. For example, if a willing party can take the reject water and benefit from it, this would be the easiest solution. However, willing recipients may be hard to find. Disposal at Sea would only be possible if in close proximity to the coastline. This option is not available to places like El Paso. Even if disposal at sea were considered, some discharge limits would apply and may not be met without further treatment. No one treatment method fits all scenarios, however, the more that the reject volume can be reduced, the better the choices for final disposal. The primary options for brine reject disposal are shown below.



Evaporation Ponds - Evaporation Pond or Solar Pond use is limited to regions where the evaporation rate exceeds the annual precipitation. Desalination plants located in arid areas such as the Southwestern United States could consider such treatment methods. The design of the evaporation pond should include liners, leakage monitoring, and accurate sizing calculations. The sizing calculation can be complicated as several competing factors must be evaluated including inflow rate, annual precipitation, and evaporation rates. Sufficient excess capacity must be provided. The cost of construction

will vary quite a bit depending on the terrain and site conditions. Once installed, the actual operating costs are relatively small, however, one cost often overlooked is the closure of the pond at the end of the life.

Deep Well Injection - Deep well injection is used for many difficult to deal with waste streams. However, the option of Deep Well Injection is limited by the underlying geology. Any deep well discharge must be protected against mixing with drinking water aquifer supplies. The permitting process can also be long and arduous. Usually deep well injection is a last resort since it is more difficult and time consuming than other methods of disposal.

Costs for disposal wells like the one shown on the right are mostly related to permitting, drilling, and logistics. Very often, disposal well locations are not in the same area as well water supply for drinking water. This means that brine reject would need to be piped and pumped dozens of miles to a suitable location with porous rock formations. [13] One other factor is that in many areas of the United States, oil wells are becoming depleted. Such spent wells are candidates for disposal wells. There are some costs involved in converting the well to a disposal well, but overall there are cost savings if existing wells can be used for this purpose. [10]



Advanced Thermal Evaporation Methods - Thermal Evaporation methods include Brine Concentrators and Crystallizers. Brine Concentrators are used extensively for wastewater applications and employ a falling film evaporator with vapor recompression. Once started, operating costs are manageable. The vapor recompression provides much of the needed thermal energy. The system must be protected against scaling and fouling of the heat exchange surfaces. These systems are capable of reaching up to 15% total solids in the final brine slurry. Crystallizers rely on thermal evaporation of dissolved solids. As the water is flashed off, the solids will begin to crystallize in the unit and are then purged for disposal.

Vibrating Membranes as an Option for Brine Treatment

With new regulations as part of the Clean Water Act and with the advent of new technologies to address this problem, many municipal facilities are re-evaluating their existing methods. One of the new developments includes the new open channel plate and frame type polymeric membrane filtration systems. There are several types including the VSEP (Vibratory Shear Enhanced Process) made by New Logic Research of Emeryville, California. Competition and scientific advances have greatly reduced the cost of membrane systems making them more attractive for treating a variety of wastewaters.

Reverse Osmosis was previously not appropriate due to solubility limits. Now with this limitation removed as in the wide channel flow membrane modules like VSEP, RO membranes offer an excellent alternative to increase overall yield of drinking water and reduce the reject volume to be handled. RO VSEP membranes can be used in parallel and in series to handle any flow and produce nearly any water quality needed.

The V◇SEP filtration system incorporates a modular design, which makes it compact. Because the basic design is vertical rather than horizontal, the needed floor space per unit is inherently less than other types of dewatering systems. The V◇SEP does require up to 17' in ceiling clearance. In most industrial applications ceiling clearance is ample, it is floor space that is limited.

Benefits of the V◇SEP Compact Design:

- 1] Easily added into an existing system to enhance performance
- 2] Can be installed in areas where space is at a premium
- 3] Is easily portable and can be moved from plant to plant
- 4] Can be installed as multiple stage system or as single stage
- 5] Can be "chain linked" to any number for any process flow demand.

Very often floor space is so limited, or the system being designed is so large that a separate structure is built to accommodate the treatment system. In such cases, the fact that the V◇SEP units are vertical and compact, it may be able to fit into an existing area of the building or it will reduce new building costs by requiring less space. Construction costs of \$80 to \$120 /square foot for new industrial buildings can add up and are a consideration when figuring the overall cost burden of a completed system. In addition to the limited space required for the mechanical components, the actual filter area has been designed in such a way as to be extremely compact and energy efficient. In the largest model, the "Filter Pack" contains 2000 Square Feet of membrane surface area, about the size of a medium size house. This 2000 SF of membrane has been installed into a container with a volume of about 15 Cubic Feet.

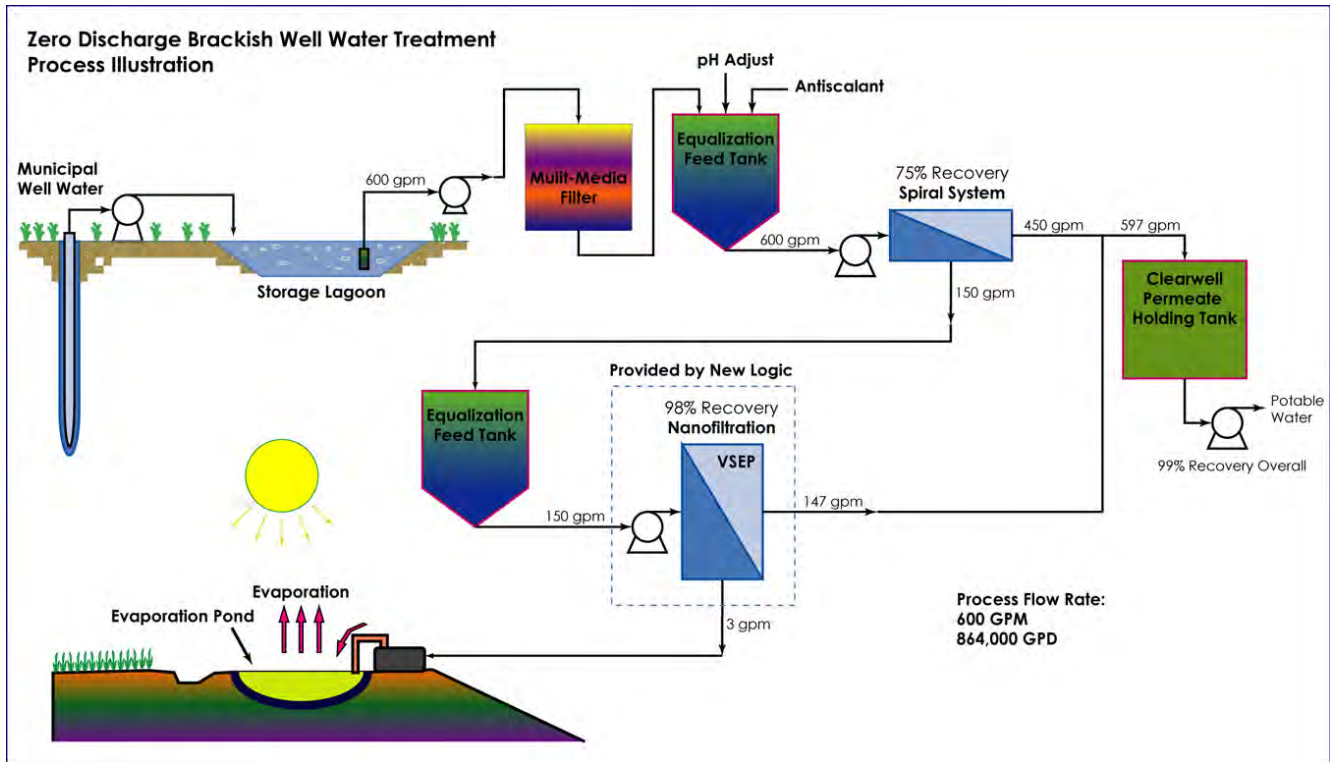
In the case of Brackish RO Reject treatment, the primary benefits are the increased treated water yield and the volume reduction of reject for disposal. In the test case shown earlier, only 3 gpm of reject would be left out of an initial 600 gpm of feed flow to the treatment plant. The reject volume would be 150 gpm, without the VSEP. Since the cost of Zero Discharge will hinge on the final disposal of brine, reduction of the reject volume is critical.



VSEP Module

VSEP Process Conditions

A process schematic for the proposed project related to the test case described above is shown on the following page. When a VSEP system is added on as a second stage, the well water is fed through the multi-media filter and then the water is pH adjusted and anti-scalant is added. The water is then fed to a spiral membrane system at the rate of 600 gpm. The spiral system produces 450 gpm of treated water and 150 gpm of brine reject. This brine reject would be then sent to the V◇SEP treatment system at a rate of 150 gpm and a pressure of 450 psig. Industrial scale V◇SEP units, using Nano-filtration membranes are installed to treat the spiral reject flow. The final reject stream after VSEP of 3 gpm would be discharged to an evaporation pond or other disposal method. V◇SEP generates a permeate stream of about 147 gpm which is blended with the stage one filtrate from the RO. The permeate contains approximately 1 mg/L of total suspended solids (TSS), and a low level of total dissolved solids (TDS), all well below the standards for drinking water. Membrane selection is based on material compatibility, flux rates (capacity) and permeate quality requirements. In this example, the TSS reduction is over 99%. The permeate quality from the V◇SEP can be controlled through laboratory selection from more than 200 membrane materials available to fit the application parameters.



VSEP Process Schematic for Recently Pilot Tested RO Reject Application

Economic Value

New Logic’s V◇SEP system provides an alternative approach for Brackish RO Reject treatment applications. In a single operation step, V◇SEP will provide ultra-pure water and reduce TOC, TSS, TDS and color to provide a high quality filtrate free of harmful microorganisms. The justification for the use of V◇SEP treatment system in your process is determined through analysis of the system cost and benefits including:

- Large land area for evaporation ponds not required as would be without VSEP
- Simple automated treatment system requiring little operator involvement
- Small system footprint
- No chemical pre-treatment addition required
- Non-Thermal process with low operating costs

Operating Cost Comparisons	VSEP Membrane Concentrator	Thermal Brine Concentrator	Injection Well Disposal	Evaporation Pond Disposal
Capital Cost Ratio	1.00	7.43	11.25	3.93 [13]
Power Consumption	\$0.21/1000 gal	\$4.44/1000 gal	---	---
Chemical Consumption	\$0.02/1000 gal	\$0.18/1000 gal	---	---
Membrane Replacement	\$0.21/1000 gal	---	---	---
Operation & Maintenance	\$0.18/1000 gal	\$1.59/1000 gal	---	---
Total Operating Costs	\$0.45/1000 gal	\$6.21/1000 gal [12]	\$1.13/1000 gal [11]	\$0.91/1000 gal [13]

The VSEP Capital and Operating costs shown above correspond to the case that was recently pilot tested and described above. Actual VSEP results can vary depending on the make up of the brackish water feed source. Pilot testing should be done to verify system throughput and the resulting capital and operating costs.

Due to the lack of need for pre-treatment, the VSEP technology has been shown to be competitive with conventional spiral membrane systems and could even replace the spiral system completely yielding up to 98% recovery of treated water. A desalination plant composed entirely of VSEP would be a very cost effective alternative to existing conventional membrane plants. However, in such cases where an existing spiral membrane system is operating and where additional yield of treated water is desired, VSEP can be used as a complimentary technology. Compared to all other brine disposal methods, VSEP is much less expensive to own and operate.

Conclusion

Arid regions of the United States such as the southwest states of California, Arizona, New Mexico, and Texas are rapidly growing in population. Local Water Utilities are scrambling to come up with economical sources of drinking water. There has been a lot of research on this subject and this prospect poses a challenge for creative engineers working on the project. Due to competition and scientific advances, membranes are becoming a much more economical method of delivering drinking water from any source.

New Logic has been contacted by many engineers in the Southwest and is currently working on various research projects to measure the suitability of using VSEP technology to treat brine reject from brackish water desalination plants. The initial results are very promising and warrant further consideration. The VSEP technology has been used for more than a decade in the chemical processing industry. This unique opportunity for treatment of RO Reject from desalination plants comes at a time when the VSEP technology is mature, proven, and very cost effective compared to other competing methods.

Addition of a VSEP membrane concentrator system would significantly reduce the volume of brine reject that needs disposal. The reduction of the volume to be treated greatly simplifies the choices for final disposal. In the test case described above, an evaporation pond would only need to be 2% of the size it would be without the VSEP brine concentrator. Reducing the size of the evaporation ponds not only reduces the costs, but has aesthetic and political benefits as well. In addition to helping to solve the brine disposal problem, addition of the VSEP system to an existing desalination plant will increase the yield of treated water to as high as 98% as shown in the case described above.

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Publications:

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- 5 Using VSEP for Polymer Diafiltration and Desalting
- 6 VSEP Filtration of Desalter Effluent
- 7 Membrane Filtration of Metal Plating Wastewater
- 8 VSEP Filtration for Glycol Recovery
- 9 Membrane Filtration and Precious Metals Recovery
- 10 Using VSEP to Treat Produced Water
- 11 Membrane filtration of Commercial Drinking Water

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- Using VSEP for Filtration of Oily Wastewater from a Waste Hauler
- Concentrating Carbon Black using Membrane Filtration
- An Examination of the use of VSEP Technology to Replace Cold, Warm, and Hot Lime Softening

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Glossary:

Batch Concentration: The machine configuration where a fixed amount of feed slurry is progressively concentrated by removal of permeate from the system. The concentrate from the system is returned to the feed tank.

Concentrate: The part of the fluid solution, which does not permeate through the membrane. Also called Reject or Retentate.

Feed: Also called feed slurry. It is the raw solution, which is offered for filtration. It typically has suspended solids, bacteria, or molecules, which are to be segregated from a clear filtrate, and reduced in size making a concentrate solution of feed slurry.

Filter Pack: The filtering module, which contains the membrane, layers and is housed by a fiberglass enclosure

Fouling: The accumulation of materials on the membrane surface or structure, which results in a decrease in flux

Flux: Not the same as flow rate. Flux is a measurement of the volume of fluid, which passes through the membrane during a certain time interval for a set area of membrane, ie GFD, LMH

Microfiltration: Filtration of particles suspended in solution, which are $\geq 0.1 \mu\text{m}$ or 500,000 daltons in size or weight.

Micron: A unit of measurement. 1 Micron is equal to one-millionth of a meter (10^{-6}). 1 Micron also equals 12,000 mesh or .0000394". The limit of human visibility is 40 Microns.

Molecular Weight: The number that expresses the average mass of the molecules of a compound to the mass of an atom of Carbon 12 at a value of exactly 12

Nanofiltration: Filtration of particles suspended in solution which are $\geq 0.01 \mu\text{m}$ or 1000 daltons in size or weight.

Percent Recovery: The ratio of permeate flow rate to the feed flow rate

Permeate: Also called filtrate. It is the part of the solution, which is able to or allowed to filter through the membrane. The particle size of solids still suspended is determined by the pore size of the discriminating membrane.

Reverse Osmosis: Filtration of particles suspended in solution, which are $\geq 0.001 \mu\text{m}$ or 100 daltons in size or weight.

Ultrafiltration: Filtration of particles suspended in solution which are 0.01 to $0.1 \mu\text{m}$ or 1000 to 500,000 daltons in size or weight.

Exhibit T:
Fugitive dust control

Fugitive dust control

The problems arising from coal dust emissions can be severe, and the methods to control the emissions can sometimes be inadequate. However, a recent project undertaken in Germany has overcome these problems, eliminating the risk of explosions while keeping costs low.

Christopher F. Blazek, Benetech GmbH, Germany, Terry Rogers, Mibrag mbH, Germany

High levels of airborne dust which accumulate during coal mining and power plant operations can be highly problematic for operators. Difficulties arise for worker health and safety issues, possible violation of operating parameters, fire and explosion hazards, increased maintenance expenses, and fuel loss during transit. Recent coal-fired power plant explosions in the USA dramatically illustrate the need for proper coal dust control.

Three types of dust control methods exist - containment, collection and suppression - all of which are widely used with varying degrees of success. Each also has its own limitations, however, including collection inefficiencies, high maintenance costs and high installation costs.

To overcome these limitations, Benetech GmbH has introduced a new dust suppression technology to Europe, and recently installed a residual suppression system at the Mibrag mbH Profen brown coal mine in Sachsen-Anhalt, Germany. Benetech GmbH, a subsidiary of Benetech Inc., was formed in 1997 to provide dust suppression solutions to industries in Europe. It entered into an agreement with the Mitteldeutsche Braunkohlengesellschaft mbH (Mibrag) to supply a dust suppression system at its Profen brown coal open pit mine located in the Sachsen-Anhalt region of Germany. Mibrag evolved from the 1994 privatization of the Mitteldeutsche Braunkohlenwerke AG and more recent acquisition by the consortium of Morrison Knudsen, NRG Energy and PowerGen. The Profen mine is capable of producing 9 to 11 million t of brown coal annually.

The success of the Benetech dust suppression system at Profen led to the award of a second contract to provide dust suppression systems at Mibrag's newly refurbished Schleenhain mining operations. Schleenhain is an open-pit brown coal mine located in the Freistaat Sachsen region of Germany. Mibrag's DM600 million (\$330m) investment in the unified Schleenhain mine, with fields in Schleenhain, Peres, and Groitzscher Dreieck will have a coal production capacity of more than 10 million t per year when it begins operation in the summer of 1999.

The principle recipient of the brown coal will be the nearby new Lippendorf power plant to be supplied with coal via a long distance conveyor system. In addition to this conveyor, Mibrag has installed new mining equipment, conveyor systems, and coal blending stockyard. Special attention has been given to noise and emission issues, which include fugitive dust emissions.

Environmental hazards

Because of the friable nature of coal, large amounts of dust can be generated during the mining, transportation, storage and handling processes. Studies have shown that wind losses alone from a train can reach one to three tons of dust per car during transit. Coal dust causes the most problems at mines and power plants during handling, unloading and storage activities. This includes the generation of particulate matter (dust) that drifts and settles on adjacent property.

Health and safety factors also must be considered along with environmental factors. Safety factors include the inherent hazard of spontaneous combustion and the explosive nature of coal dust. It is not uncommon for coal piles to generate hot spots that can ignite coal dust during the handling process. A number of recent coal dust related explosions have been reported which illustrate the need to control coal dust emissions. High levels of fugitive dust also increase equipment maintenance and shorten the life of coal handling equipment.

Many countries have adopted environmental standards for fugitive dust emissions and health and safety regulations pertaining to allowable respirable dust levels. Methods and equipment to control fugitive particulates produced in handling coal include containment, suppression and collection systems. Containment includes the installation and proper maintenance of skirtboards, belt scrapers, baffles, and conveyor hoods to contain and limit airborne dust. However, even well engineered systems have limited success with the dusty lower rank coals and have no impact on dust control during transport or storage.

Mechanical dust collection systems, such as baghouses, can be used to collect dust from strategic locations along the material handling system. No moisture is introduced which reduces the heating value of the fuel. Collection efficiencies can reach nearly 100 per cent, but maintenance costs are high. These systems also have high installation costs, the

collected dust must be treated to avoid the risk of fire or explosions, and the system does not control dust generated downstream of the collection point or at the coal pile.

Dust suppression systems use strategically placed manifolds to introduce a suppressant solution that controls airborne dust levels. General types of dust suppression systems include wet surfactant systems, foam surfactant systems, and residual suppression systems that use binders, humectants, and surfactants to provide long-term dust control for coal storage as well as in handling systems.

The benefits of these systems include reduced equipment costs, reduced power and maintenance costs relative to mechanical collection systems, and residual dust suppression significantly reduces dusting at downstream coal transfer points and coal storage piles.

Dust abatement needs are most acute where heavy-duty mining dump trucks or rotary and bottom-dump coal cars unload. These operations emit clouds of dust. Chemical dust suppression and collection systems are most frequently used to control dust emissions at these points as well as at conveyor transfer points and during the stack-out and reclaim process.

Dust suppression involves the application of chemically treated water via sprays or foam to the coal stream to minimize fugitive dust emissions. Surfactants in the chemical package wet the coal and dust particles, effectively altering the weight /mass ratio and cohesiveness of the material. By wetting the dust, either as it lies in the material body or as it escapes off the pile, the mass of each particle is increased, so it is less likely to become airborne. The suppressant solution also increases the cohesion of the material, making it more difficult for air currents to pick up small particles adhering to larger particles.

Wet suppression: This technique combines the use of water with an effective wetting agent. After being wetted, gravity forces the dust particles downward into the coal flow. The technology effectively controls dust at the dumper area and can provide a degree of residual protection during multi-transfers. This residual effect allows for few application points which minimizes water addition and equipment and installation costs.

Foam suppression: The foam-spray technology, effective for many coal-handling situations, lays out a heavy spray of foam that blankets the dust before a cloud can rise. Foam dust suppression works by reducing the surface tension or "static charge" of individual dust particles and increasing the molecular attraction between fugitive dust particles and larger coal pieces. Mixing foaming surfactants, water and compressed air in proper proportions generate the foam. Application of foam dust suppression into transfer chutes and crushers can increase immediate and mid-term dust suppression through upcoming transfer points. This system has an extra advantage in that it minimizes the amount of water used and applied to the fuel.

Residual suppression: Residual dust suppression consists of binders, humectants and surfactants applied to coal on the conveyor belt that transports the fuel from below the dumper to the coal storage stackout. With this technology, the coal can be treated just once and it maintains residual dust control throughout the conveyor system, stackout, and during stock piling and the ground movement of coal. Depending on the length of stackout, residual suppression can reduce airborne dust levels during the reclaim process. There is a second benefit in using the residual dust suppression system in that it acts as a compaction enhancement agent as the coal is spread into active or reserve piles.

Comparative studies of water systems with chemical systems find that approximately two to four per cent surface moisture is added to coal by water spray systems. This compares to 0.15 per cent to 1.0 per cent for chemical systems. The least amount of moisture addition, typically less than 0.2 per cent, is produced by foam technology.

Added moisture content can pose serious consequences for boilers and the steam generating cycle. Excess water may promote belt slippage and increase the possibility of wet (and hence sticky) fines accumulating within chutes and around transfer points.

Excessive moisture can adversely affect the material's "cold weather" performance, complicate its flow dynamics, add weight (and hence cost) to material transportation, and reduce the effectiveness of conveyor belt cleaning systems.

The Mibrag project

To control dust emissions at the Profen and Schleenhain mines, Benetech GmbH engineers conducted a detailed site survey of both mining operations. This included the development of the following site specific dust control goals:

- Address fire and/or explosion potential

- Determine when and where dust control is needed (at dumpers, handling, stackout, etc.)
- Anticipate the ease of dust control system changes for possible conveyor modifications or changes in coal properties
- Review costs for equipment and chemicals
- Include the need for a clean and healthy work environment to meet local work regulations and fugitive dust emission limitations
- Evaluate the degree of fugitive dust from storage piles and transfer points
- Consider system reliability, system maintenance and current work force load
- Establish housekeeping and worker productivity goals.

After the goals were determined, Benetech evaluated the available dust control methods for suitability. As no mining or power plant operation is the same, Benetech developed a custom solution for each mine. At Profen, Benetech chose its BT-415 residual dust control system.

The Profen brown coal mine is located near the towns of Zeitz and Weissenfels in the south of the federal state of Sachsen-Anhalt. Coal is mined from three seams; the Saxon-Thuringian lower seam, the Thuringian main seam, and the Boehien upper seam, covering an area of roughly 25 km². Nearly 32 km of conveyor belts exist at the site and Mibrag routinely collects dust and noise readings to ensure that legal requirements are met.

Benetech's solution included the installation of application systems at stations 5a, 43, and 45. Each application system consists of an enclosure with a water pressure booster pump and chemical dosing pump. These fully automated systems precisely meter chemicals from the adjacent chemical storage tank to a stream of metered water. At station 5a the chemically laced water stream is sent under pressure via 50 mm (outside diameter) high density polyethylene pipes to six spraybars, operating at 4 bar pressure, to the conveyor transfer points. Station 43 is similarly equipped, feeding nine spray bars while station 45 feeds six spray points. The effectiveness of this system prompted Mibrag to select a Benetech dust suppression system for their Schleenhain mining operations.

The Schleenhain mine, located in the Saxony region, was temporarily shutdown in 1995 to convert the mine to full conveyor belt operation. The mine is now scheduled for start-up in the summer of 1999 to supply brown coal to the newly constructed adjacent Lippendorf power plant. With a reserve of more than 400 million t of coal, the mine is expected to operate through 2040. An important element of the mine refurbishment is noise and emission protection, including fugitive dust control.

At the Schleenhain mine the Benetech site survey indicated a need for both residual and wet dust suppression systems at a number of locations. A BT-415 based residual dust suppression system was installed near the screen and breaker station as shown in Figure 1. This system is designed to apply a suppression spray at the discharge of the sieve, discharge of the crusher, and tail of conveyor 73 following the sieve and crusher chutes.

An example of the manifold placements is presented in Figure 2. Spray locations are placed to maximize penetration into the moving coal stream. All water, chemical and solution piping and the chemical storage tank is heat traced and insulated to prevent freezing down to -25 degrees C. To prevent freezing at the spray tip assembly and flexible hose connections, compressed air is injected at shutdown into these components during cold weather operation.

The Benetech designed control system utilises Siemens' series programmable controller with Profibus communication network capabilities. Through this network Benetech can retrieve data concerning conveyor belt operations and report data concerning the functions of the dust suppression system. A Benetech installed ultrasonic level transmitter signals coal at the head of conveyor 72. Variable speed chemical pumps control the application rate based on the level of coal on the conveyor. In addition to retrieving data from the communication system, the Benetech control system provides data indicating various operating parameters such as:

- System operating conditions
- Chemical storage tank level
- Water flow rate and total

- Chemical flow rate and total
- System alarm conditions such as water and chemical pump failures

A Benetech BT-205W wet suppression system is installed at the transfer tower shown in Figure 3 and is designed to apply a suppression spray at the transfer chute from conveyor 75 to 80 and at the transfer chute from conveyor 76 to 90. An example of the manifold spray points on the conveyors is presented in Figure 4. As can be seen, the spray points immediately follow the impact areas on the conveyor system. This system is similarly equipped with a water pressure booster pump and chemical-metering pump. Adjacent to this container is a 25 000 l carbon steel heat traced and insulated storage tank to store the BT-205W surfactant. The tank is of double wall construction to eliminate the need for a retaining structure.

An effective approach

Special attention was given to factors such as manifold placement, air velocities, spray penetration into the coal flow, spray patterns, and chemical effectiveness. Even the best designed dust suppression system will fail if the suppressant chemical is not formulated correctly and is not delivered to the correct location to allow intimate mixing with the dust fines.

Chemical dust suppression systems are widely used in the USA to control fugitive dust emissions. The effectiveness of this approach in treating brown coal has been shown at the Profen mine. A similar system has been installed at the Schleenhain mine and will be operational this summer. At both locations a major factor in their success is the unique systems that were design for site specific conditions.



Figure 1. Dust suppression system and chemical storage tank at Schleenhain mine

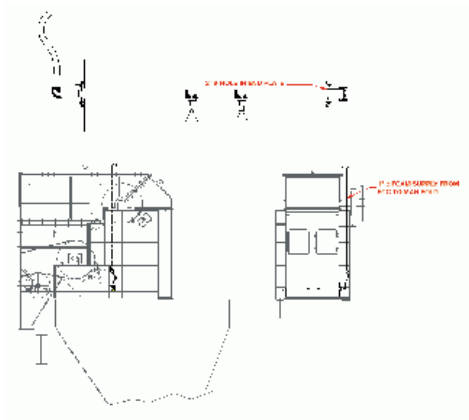


Figure 2. Example spray manifold placement in chute

[Click here to enlarge image](#)



Figure 3. Head of conveyor at transfer tower

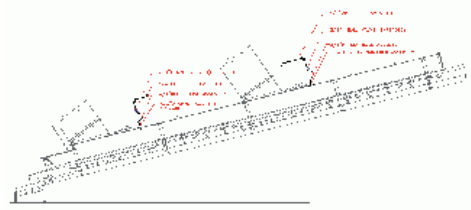


Figure 4. Example spray manifold placement on conveyor system

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