

V \diamond SEP for Polymer Diafiltration (Desalting)

A cost-effective and efficient processing solution

Introduction

Recent technological advances in membrane architecture and system design have created a new opportunity for efficient diafiltration or desalting of various organic polymers and inorganic chemicals. V \diamond SEP, (Vibratory Shear Enhanced Process), developed by New Logic makes it possible to wash larger solutes and remove smaller contaminant solutes without the fouling problems exhibited by conventional membrane systems. The V \diamond SEP membrane system is capable of extremely high recoveries of filtrate, thus minimizing the volume of wash water and consequently reducing treatment costs.

Extremely high shear energy is delivered directly to the surface of the membrane eliminating the gel layer buildup while maximizing flux rates. By deriving shear from the membrane movement, V \diamond SEP delivers shear rates 10-15 times higher than that of conventional cross flow systems. Unlike conventional membrane configurations, the direction of the shear is changed at a frequency of 50 times per second creating over 200 G's of force with each change in direction. The V \diamond SEP treatment system uses Nanofiltration or Ultrafiltration membrane modules to sequentially replace the solvent and remove permeable species that are not desired by using continuous dilution and removal of filtrate. The solvent and solute are fed to a process tank and a side stream of de-ionized clean water is added on a continuous basis. The permeate from the filtration system is sent to sewer as new de-ionized water is continuously added to replenish the volume of permeate which is removed. This process continues until the level of undesirable permeable species has reached a low enough concentration.



The VSEP Advantage

Membrane based separations of liquids from solids have become increasingly important during the last 20 years. The increased interest in membrane applications has been driven by several unique advantages offered by membranes over competing separation techniques. Membranes are replacing many conventional separation processes such as Evaporation, Rotary Drum Vacuum Filtration, Centrifugal Separation, Clarifiers, and Flocculation and Sedimentation.

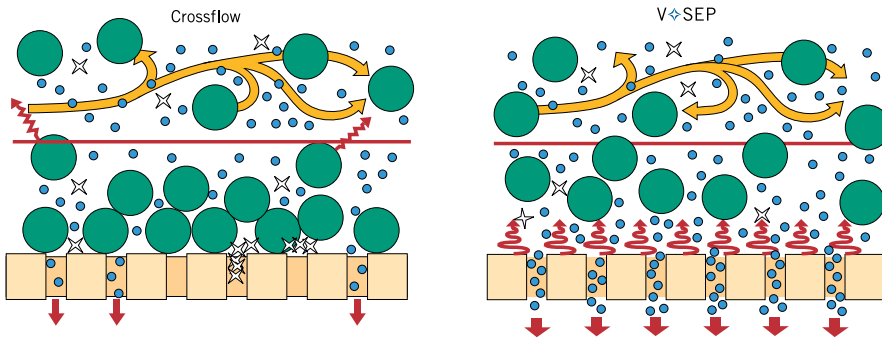
Membrane systems designers have struggled to reduce fouling by using tangential flow or "cross flow" filtration. In this method, membrane leaf elements are placed in a plate and frame, tubular, or spiral-wound cartridge assembly, through which the feed stream is pumped at a high velocity to create shear forces. The shear forces produced on the face of the membrane are intended to keep the

membrane clean. Even with high velocity pumping, which is wasteful of energy, the use of cross flow membrane systems are limited to low-viscosity (watery) fluids with relatively low levels of suspended solids.



A 36" V \diamond SEP filtration unit

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



Sinusoidal shear waves repel suspended solids in the V-SEP and keep membrane surfaces clear producing high filtration rates per unit area

New Logic has developed an alternative method for producing intense shear waves on the face of the membrane leaf element. The technique is called Vibratory Shear Enhanced Processing (V-SEP). In a V-SEP system, the feed slurry remains nearly stationary, moving in a leisurely meandering flow between parallel membrane leaf elements. The leaf elements move in a vigorous vibratory motion parallel to the face of the membranes. The shear waves produced by the membrane vibrations cause solids and foulants to be repelled and liquid to flow through the membrane pores unhindered.

little as 10% of the energy required to run the system is converted to shear energy, VSEP enables nearly 99% of the total energy to be converted to shear at the membrane surface where it can do the most good.

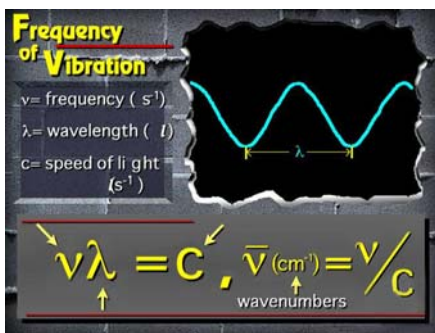
By running a V-SEP unit at 150 p.s.i. trans-membrane pressure, for example, the attainable filtration rate is typically 5 to 10 times higher than that achievable by cross flow systems. Because V-SEP does not depend on the shearing forces of crossflow, the slurry can be extremely viscous and still be successfully dewatered. The final product is very thick when it is removed from the filter pack but will not stick to the vibrating disc elements.

The very high shearing produced by V-SEP has been shown to prevent diminishing of filtration rates, due to fouling. V-SEPs resistance to fouling is greatest when the membrane microstructure is a non-depth type of filtration media (analogous to a screen or colander). Membranes containing cylindrical pores are ideal. Non-stick surfaces of Polypropylene and Teflon also resist fouling when used in V-SEP machines, especially when the tightest possible pore size is selected.

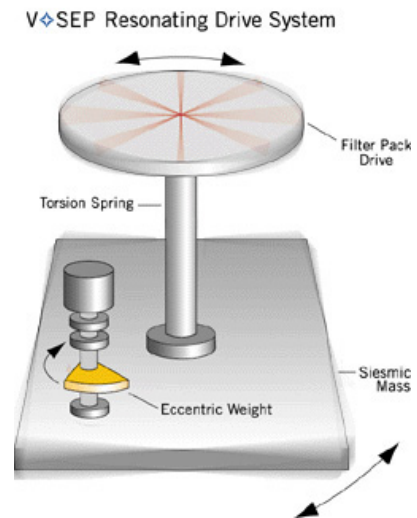
Because shear originates at the membrane surface, and not in the process fluid, a V-SEP machine can be operated in a single pass configuration. In a single pass

operation the feed material enters the filter pack, experiences the shear and is dewatered progressively as it cascades from disc to disc. Final product, once it reaches the desired end point concentration, exits the stack. The two independent control parameters are shear and pressure. The vibration amplitude of the disc stack creates shear. Pressure is created by the pump and is controlled by selecting a pump that can produce adequate feed pressure at the design flow rate.

The torsional vibration of a disc plate accomplishes extremely high shear in a resonant spring mass system. The membranes, which are attached to this plate, move at an amplitude of 5-10 degrees and a frequency in the range of 50 Hz. The fluid in the filter pack moves slowly through the pack in a serpentine fashion parallel to the membrane trays. The motion of the filter pack creates a highly focused shear zone at the wall (membrane surface). Retained solids at the membrane surface are effectively removed by the shear, allowing for higher pressures and higher permeate rates.



In an industrial V-SEP machine, the leaf elements are arrayed as parallel discs separated by spacers. The disc stack is moved in a torsional oscillation, like the agitator of a washing machine. This produces a shear rate at the membranes of about 150,000 inverse seconds, literally ten times greater than that obtainable in cross flow systems. In contrast to cross flow systems where as



V-SEP Drive System

As shown by the previous illustration, V \diamond SEP is simply two masses connected by a torsional spring, which is excited at its natural resonant frequency. One mass (the Filter Pack) is lighter, holds the membranes, and moves with high amplitude. The other mass, the heavier Seismic Mass, moves with smaller amplitude proportional to the ratio of the two masses. The use of two counter-rotating masses allows the system to resonate without attachment of the device to a rigid surface. An AC motor creates the excitation. The motor spins an eccentric weight that is attached (through bearings) to the seismic mass. Since the eccentricity of the weight induces a wobble, the seismic mass begins to move as the motor speed increases. This energy is transmitted into the torsion spring and begins to move the Filter Pack at the top, but at 180 degrees out of phase. As the motor speed approaches the resonant frequency, the amplitude of the moving Filter Pack reaches a maximum, and greater motor speed will only decrease the amplitude. V \diamond SEP is run below the maximum amplitude to reduce spring stress and ensure an infinite spring life.

The entire system rides on an isolator to allow for free movement. The required motor speed for vibration of the Filter Pack is not quite attainable by normal power line frequency, so a Motor Speed Controller is used. The Speed Controller allows precise adjustment, at the front control panel, of the Filter Pack vibration amplitude. Proper adjustment of the vibration amplitude can optimize the use of electrical power with respect to performance.

The main function of the electrical control system is to protect the Filter Pack. Conditions that may cause malfunction or damage are detected and appropriate actions are taken. A Programmable Logic Controller (PLC) and a Touch Screen / Keypad Display

(TKD) are used for system control and operator interface. These components allow the control system configuration and timing to be flexible. The four most commonly measured and displayed process variables are Feed Pressure, Permeate Pressure, Concentrate Pressure, and % Motor Load (Vibration). Operator configurable alarms insure that process values remain within their respective safe ranges.

Ultrafiltration Membrane Theory

The filtration rate, or flux, of an Ultrafiltration membrane depends on several factors including the MWCO of the membrane, the concentration of the solutes in the process solution, the operating pressure, and temperature of

Ultra Filtration Membrane

Composition	Polyvinylfluoridene
Nominal Pore Size	250k mwco
Operating Pressure	0-140 psi
Continuous pH Range	2-12
Max Flat Sheet Temp	70°C

the molecular filtration system. As in all filtration systems, filtration rates are inversely proportional to solute concentration. Membrane flux on clean water will typically be higher than flux on the feed material to be dewatered.

The selectivity and retentivity of a membrane are characterized by its molecular weight cut off (MWCO). This method is reasonably precise when dealing with a single type of solute consisting of molecules of uniform size, shape, and charge. Most membranes do not have completely uniform pores, but exhibit a pore size distribution that may also affect the degree of separation attainable. By convention, a molecular weight cut off of 10,000 means that the membrane would retain 90% or more of solutes of molecular weight 10,000 or more. Molecules and ions with low molecular weight (e.g. less than 500) pass freely through the membrane, and species with higher molecular weights up to 10,000 are partially retained according to the pore size distribution of the membrane.

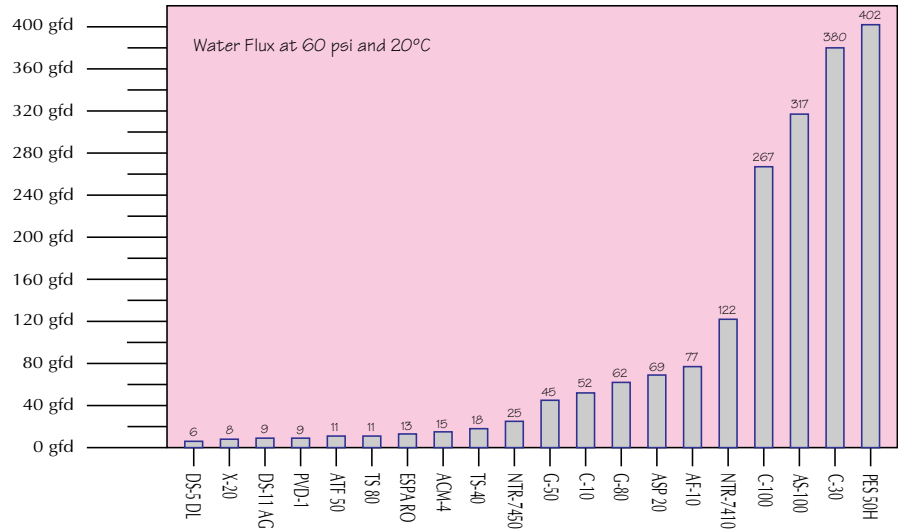
Adsorption is the phenomenon where retained solutes in the process solution bind to the surface of the molecular filtration membrane. The adsorption process tends to block or occlude the pores of the membrane resulting in increased retention and decreased flux for the membrane and thus may substantially reduce the recovery of the solute of interest. Adsorption is dependent upon the characteristics of the membrane polymer. New Logic will pilot test using a variety of membrane chemistries to determine which chemistry is compatible with the feed materials when it comes to adsorptive fouling.

The vibratory nature of V \diamond SEP helps to reduce or eliminate colloidal fouling, which is simply the impaction of suspended solids against the membrane surface due to the driving pressure of the system. Ultrafiltration is an excellent preparatory technique for other separation methods. It is often used to reduce process solution volume during purification procedures, or to enhance detection and quantitation of solutes present in low concentration. Molecular filtration often provides advantages over the older techniques of separation, such as precipitation, evaporation, vacuum microfiltration.

Molecular Ultrafiltration is used for

- Density gradient separation
- Fractionation of macromolecule solutions
- Recovery of products
- Removal of bacteria and viruses
- Processing of pigment dispersions

For large-scale process applications, molecular filtration is rapid, simple and relatively inexpensive compared to traditional preparatory techniques. Concentration is the retention of molecular species by filtration of microsolute through the membrane.



Membrane pore size determines roughly what flux rates will be. However, other permeating characteristics also affect flux. (hydrophilicity, asymmetric, non asymmetric, complexity of pore structure). Two membranes with the same MWCO may have different water flux results at the same pressure.

Volume reduction of a macromolecular solution is accomplished when solvent is forced through a molecular filtration membrane with pressure. As the solvent and the lower molecular weight species pass through the membrane and emerge as ultrafiltrate, the initial volume is progressively reduced and the higher molecular weight species are concentrated. Molecular filtration rate is a function of solute type and size, concentration, temperature, homogeneity of the sample being concentrated and MWCO of the membrane selected.

In molecular filtration, the flow rate or flux is affected by concentration. As the concentration of retained species increases, the flux will decrease. At higher concentrations and pressure, the flux will vary inversely with the log of the concentration.

Desalting by “diafiltration” involves the removal of unwanted low molecular weight species, such as salts or solvents without significantly reducing the number of macromolecules in the solution. In many applications, it is

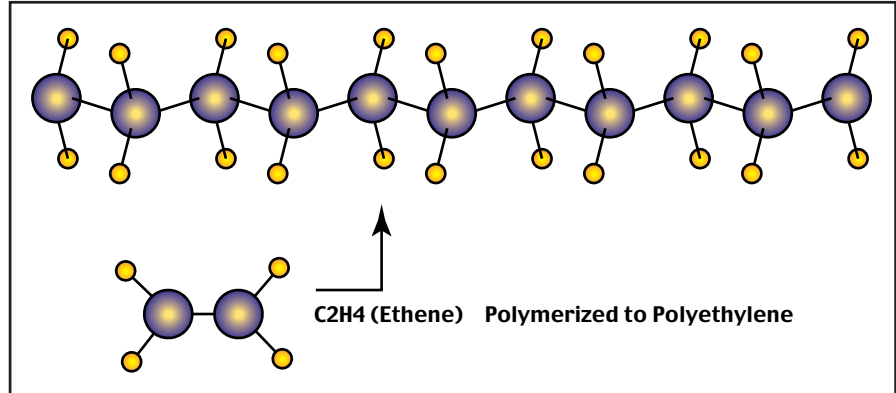
necessary for the solvent in the process solution to be nearly completely exchanged. During molecular filtration, microsolute freely pass through the membrane and maintain original concentrations on both sides of the membrane. A two-fold concentration of a solution will reduce its volume by half and increase the concentration of retained macrosolute by two, but the concentration of microsolute will remain constant.

If the objective is to desalt the solution, one approach would be to redilute the concentrate with fresh solvent to the original volume, effectively reducing the salt concentration. In continuous diafiltration, the filtrate is removed and continuously replaced by fresh solvent at the same rate.

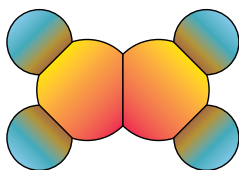
For example, almost 95% removal is achieved when the volume added is three times the original volume, over 99% removal is achieved when the volume added is five times the original volume.

Diafiltration

Ultrafiltration membranes can be used in a process known as “diafiltration”. It is used when two constituents in a liquid solvent are to be separated. The objective is to purify one or the other solids. Very often this purified solid will be a product that has significant value. During the process, concentrate is either returned to the feed tank or sent to a subsequent stage of filtration, clean water is added to the concentrated solids, and permeate is removed from the system. Diafiltration gradually improves the separation between retained and permeable species. This purification can go on into infinity, but normally there is a target level of acceptable impurities and the wash volumes can be calculated.



There are two methods of diafiltration and the use of each depends on the species that is desired for recovery. If the permeable species is sought for recovery, a method of countercurrent diafiltration can be used. In this case, permeate from the last stage can be used to wash the previous stage. This countercurrent process results in higher permeate solids in the stage first wash volume. If the rejected species is desired for recovery, a constant volume concurrent batch diafiltration will result in the most efficient process mode with the least amount of residence time. A multi stage sequence of continuous batch diafiltration can also be used and the optimum concentration for diafiltration can be calculated.



1] Using the constant volume diafiltration, you can solve for the turnover ratio required to reach the acceptable permeable species concentration using:

$$\text{Turnover Ratio} = N = \ln \left(\frac{C_0}{C_t} \right) = \frac{V_p}{V_0}$$

C₀ = Initial Concentration
 C_t = Concentration at time t
 V_p = Total permeate volume
 V₀ = Constant retentate volume
 N = Turnover ratio

2] The fractional recovery of permeable solids in the retentate is solved for as:

$$Y_r = \frac{C_t}{C_0} = \exp(-N) = 1 - Y_p$$

Y_r = Fractional recovery of permeable solids in the retentate
 Y_p = Fractional recovery of permeable solids in the permeate

3] If there are partially permeable solids the turnover ratio is calculated as:

$$\text{Turnover Ratio} = N = \ln \left(\frac{C_0}{C_t} \right) = 1 - E \left(\frac{V_p}{V_0} \right)$$

E = Rejection of solute

4] The relationship between membrane area and time for diafiltration is represented as:

$$A \cdot t = \frac{V_p}{J} = \frac{N V_0}{J}$$

A = Membrane area
 t = Time
 J = Permeate flux

5] If the flux is independent of concentration or permeable species the membrane area and time relationship is shown:

$$A \cdot t = \frac{K}{C_B \ln \left(\frac{C_0}{C_t} \right)}$$

K = Mass transfer coefficient
 C_B = Bulk Concentration of retained species
 C_g = Gel concentration

6] The Optimum Concentration for any diafiltration with the minimum amount of membrane area and time is the minimum of the plot:

$$\frac{1}{J \cdot C_B} \text{ versus } C_B$$

When fouling is absent, the optimum concentration is 0.37 x C_g. If the permeate solids are sought after, it will be preferable to concentrate the reject solids to the maximum extent possible to then diafilter with the minimum amount of wash water possible.



Case Studies of VSEP & Diafiltration

Iron Oxide Desalting:

Many pigments are found naturally. Iron Oxide is an example of this. However, since the largest use of iron ore is for the steel industry, most iron based pigments are derived from waste materials from the steel refining business. Chromium, Cobalt, and other inorganic pigments are sourced in the same way using byproducts from some other process.

Organic pigments and dyes and chemically synthesized products. The ingredients needed are purchased in raw form and then processed into the desired compound. Pigments are created from chemical reactions using liberating agents and washes to remove impurities. As with Titanium Dioxide Processing, particle size, shape, and presence of impurities is critical to product quality.

Steel mills produce iron shapes of many kinds. Very often these are galvanized. Prior to galvanizing the steel is dipped in and acid bath to etch the steel and remove rust and scale. As the bath is used the acid is consumed and Ferris salts, FeCl or FeSO₄, are produced depending on the acid used for the bath. This Iron based salt solution is obtained by pigment companies and used for processing Iron

Oxide pigment. Then the bath goes through a process of Sodium Chlorate treatment. The result is Iron Oxide and Sodium Chloride or Sodium Sulfate depending on the solution. The salt is removed by diafiltration where it is washed away using water as a solvent.

During the refining process, the Pigments are suspended in a salty aqueous slurry. This slurry must be desalted and dewatered. In the case of Iron Oxide, VSEP is uniquely able to be used as a diafiltration process and then to dewater to more than 36% solids in a single pass. 36% Solids is nearly the gel point of this material and so the diafiltration process is performed at about .37 x 30% or 11% solids. This results in a high reate of filtration with a minimum amount of wash water used. This is the important balance in any diafiltration process. During diafiltration, a UF membrane is used which will reject the pigment particles and allow the salty water to pass through the membrane.

By successive rinses, the pigment can be nearly completely separated from the salt in solution. The resulting paste is nearly pure pigment with some water.

Pigment Diafiltration Results:

Sample: Cobalt Blue Pigment
Membrane: 0.1µm Teflon
Flux: 200 GFD
Volume Reduction: 90%
Solids: 1% Initial 10% Ending

Sample: Pigment G Yellow Pigment
Membrane: G-50
Flux: 140 GFD (Diafiltration)
Volume Reduction: 90%
Solids: 1.71% Initial* 15.74% Ending

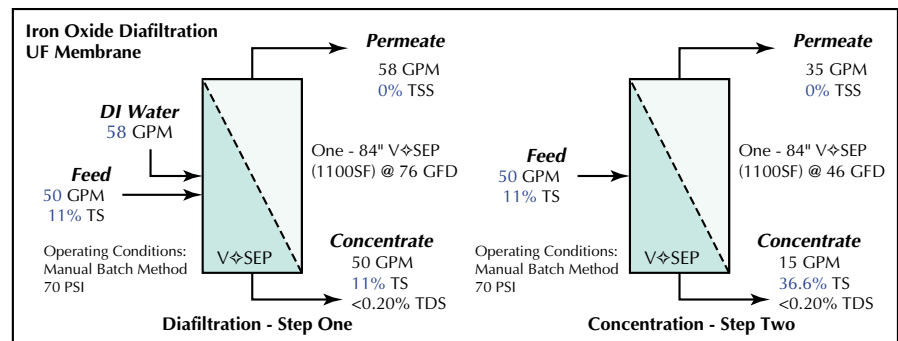
Sample: Red Iron Oxide Pigment
Membrane: AS-100
Flux: 76 GFD (Diafiltration)
Volume Reduction: 70%
Solids: 11% Initial* 36.6% Ending

Sample: Yellow Iron Oxide Pigment
Membrane: AS-30
Flux: 76 GFD (Diafiltration)
Volume Reduction: 60%
Solids: 10% Initial* 25% Ending

Sample: Molybdenum Pigment
Membrane: NTR-7410
Flux: 110 GFD
Volume Reduction: 97%
Solids: 0.08% Initial 2.67% Ending

Sample: Iron Oxide Wastewater
Membrane: C-30
Flux: 100 GFD
Volume Reduction: 95%
Solids: 0.60% Initial 8.03% Ending

* Including salts



Diafiltration - Step One:
Diafiltration of 4000 gallon batches:
Estimated washing turnover: 4 Times
Estimated liquid volume: 3560 Gal
3560 x 4 = 14,240 gal + 58 GPM = 4.09 Hours

Concentration Step Two:
Concentration of 4000 gallon batch:
4000 gal + 35 GPM = 1.90 hours
Total run time per 4000 gallons = 5.99 hours

24 hours + 5.99 hours/batch = 16,026 GPD/VSEP
Iron Oxide:
Specific Gravity = 4.5
Gel Point = 30% Solids
Average Size = 1-2µm

Case Studies of VSEP & Diafiltration

Carbon Black Desalting:

Carbon Black is a name for a family of non-crystallized Carbon forms. It is obtained from the incomplete combustion of hydrocarbons and becomes the byproduct of combustion known as “Soot”. The Morphology can be closely controlled during processing to control the size, shape, and surface area to fit a particular need. There are many different types of Carbon Black which are recognized by the particle shape and size.

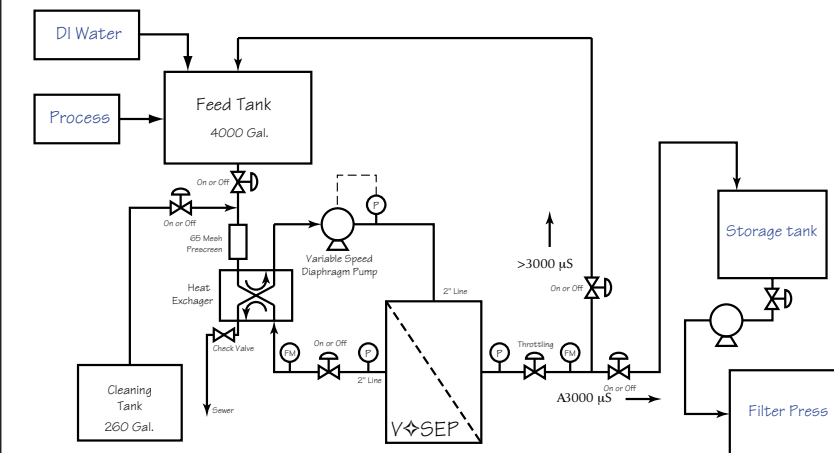
- Lamp Black
- Activated Carbon
- Carbon Pigment
- Charcoal Black
- Graphite

Carbon Particle groups are insoluble in water. The size and shape of the particles determines the use of the product. The typical makeup of Carbon Black product which is sold:

<u>Common Name</u>	<u>Symbol</u>	<u>Content</u>
Carbon	C	98.5%
Ash		0.50%
Water	H ₂ O	0.40%
Soluble Salts		0.20%
Other		0.40%

The manufacturing of Carbon is a very simple process. The largest use for Carbon Black is in automobile tires. Carbon Black adds great wear and abrasion resistance to the rubber used in tires. It has many uses where wear and abrasion resistance is desired. The other main use is as a colorant. Carbon Black is produced as soot during the incomplete combustion of hydrocarbons. There are many kinds of hydrocarbons and thus many ways to produce Carbon Black. Generally it is made from burning fatty oils or hydrocarbon gases in a controlled chamber that limits the amount of oxygen. Since oxygen is the catalyst for

Carbon Black Simplified P&ID Drawing

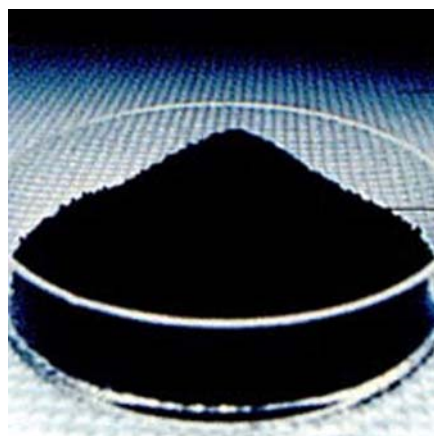


System Operation:

This process is run in manual mode and the raw product is diafiltered in the feed tank until enough of the salts and impurities are removed to meet the design criteria of the final Carbon Black product. Diafiltration includes 6 washing steps where an equal volume of De-ionized water is first added to the feed tank. Then the tank is batch concentrated by removing permeate from the system until the volume returns to the original before adding water. Then more water is added to the tank. This process repeats 6 times or until the conductivity of the concentrate is less than 3000 µS. Once the concentrate is within specification, the concentrate from the VSEP unit is diverted to another feed tank where it is stored for use by a filter press or other means of final concentration.

combustion, the amount of oxygen controls the rate of combustion and the efficiency of it. Complete combustion produces Carbon Dioxide, CO₂, moderate combustion can produce Carbon Monoxide, CO, and oxygen starved combustion produces liberated Carbon atoms which gather together as soot.

This synthesis is carefully controlled to produce the characteristics desired in the



carbon black. The amount of oxygen and the type of fuel are varied to produce the needed results. Once the soot has been formed it is air blasted or scraped off into a collection area. In its raw form, all soot deposits will have impurities which need to be removed. This is done in a refining process.

Unlike other chemical processing operations, Carbon does not require much in the way of chemical treatment or the use of liberating agents to purify the substance. It is generally washed in an acid bath with a byproduct of an aqueous salt solution slurry with the Carbon Black suspended in solution.

Successive washes with water, or diafiltration, is used to remove impurities. The quality of the finished product is highly dependent on small variations in the amount of each of the impurities which remain and also the particle size of the Carbon Black. Keeping the Carbon Black within specifications is an elaborate scientific process.

Once the diafiltration processing is complete, the slurry must be dewatered to 70% solids or higher. Some finished product is shipped as a 70% slurry. Other product is further dried and shipped as a dry powder. In any event, the initial slurry which is about 5% Carbon by weight must be dewatered to at least 70%.

V \diamond SEP is uniquely able to dewater solids and wash the solid to remove impurities. The other alternative would be centrifuges, rotary vacuum drum filters, or the like which are very expensive to operate due to the high energy consumption as well as the expensive capital equipment cost.

Case Studies of VSEP & Diafiltration

Polymer Purification:

Polymers are man made substances. They are not naturally occurring substances. Stability of the hydrocarbons is a key factor to suitability. Many techniques are used to improve the stability. Carboxylic Acid is added to the polymer chain to make it stronger. Other compounds are used to do the same. Other emulsifiers and stabilizers are used to keep the copolymer chains intact and uniform.

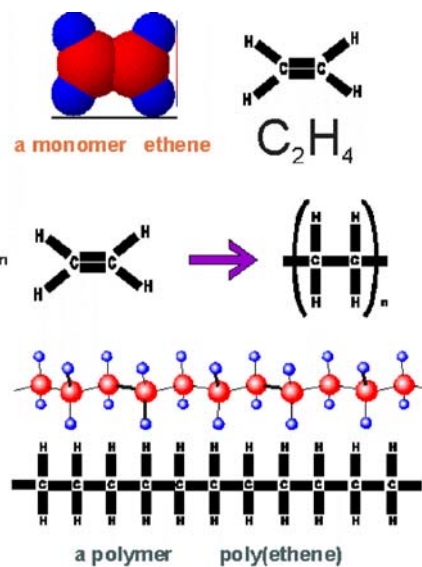
As a thermoplastic resin, polymer latexes are made as a liquid and usually the final product which is made will be a solid. The key thing is to keep the product stable through the manufacturing process until solidified. Once solidified, it is extremely stable.

For example, latex in the liquid state is extremely sensitive to pH, temperature, ionic attack, and shear degradation. Latex emulsions are also biologically active breeding grounds and measures must be taken to prevent microorganism growth. For this reason, formaldehyde or some other biocide is added to control this growth.

Manmade latex polymers are possible because of the petrochemical process where fossil fuel is processed and broken down into various hydrocarbons. The hydro-cracking process produces an assortment of Carbon/Hydrogen combinations. Styrene, C₈H₈ and Butadiene, C₄H₆ are two examples of these. When produced these are colorless odorless liquids. Hundreds of these types of thermoplastic monomers are made including esters, propylenes, amides, etc. They are better known as polymers or groups of monomers as polyester, polypropylene, polyamide, polystyrene, etc.

The hydrocarbon monomers are reacted in an aqueous solution where millions of hydrocarbon monomers are joined into complex chains. Once the monomers have been consumed and the polymer is the correct formulation, it must be dewatered. Conventional methods for this are Evaporators, Spray Dryers, and Rotary Vacuum Drum Dryers. The emulsion is dewatered to 60-65% solids and sold as product.

Because the polymers must be reacted in a 2% solution, a great volume reduction of dewatering must be accomplished to get the desired product. The main advantage for V \diamond SEP, is the fact that one piece of equipment can be used for the entire process. The uses of Polymers are incredibly large. Tires, paint, and paper coatings

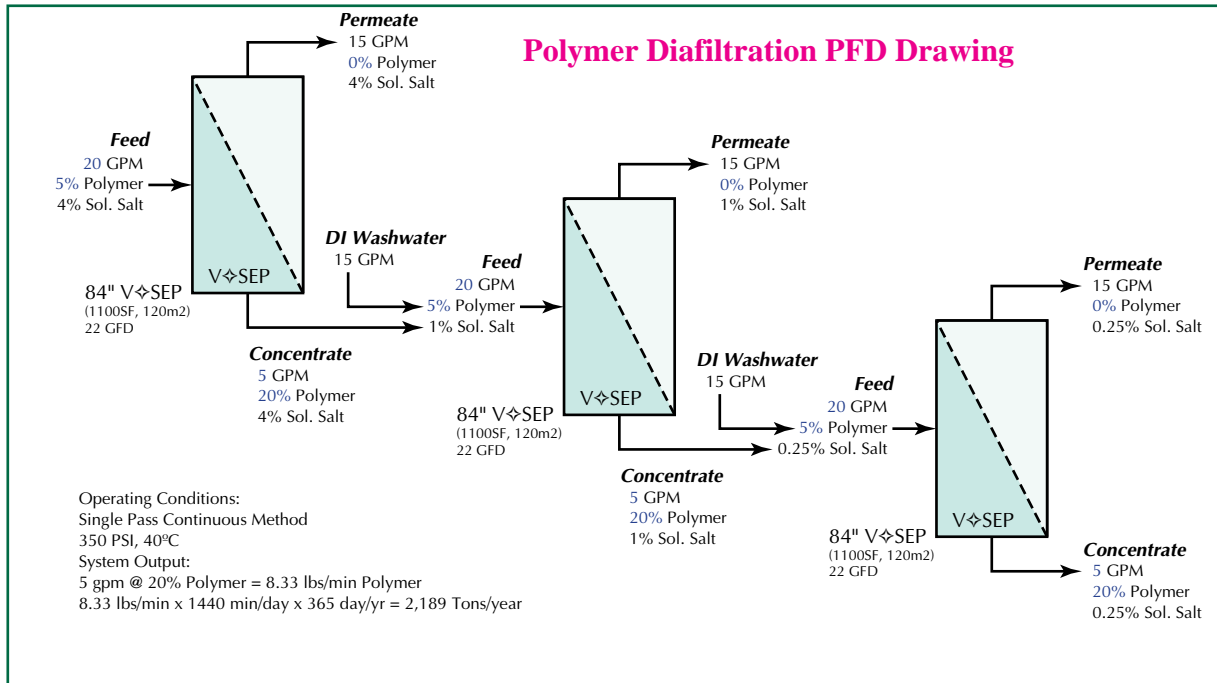


are produced by the millions of tons each year with the main ingredient being polymer emulsions.

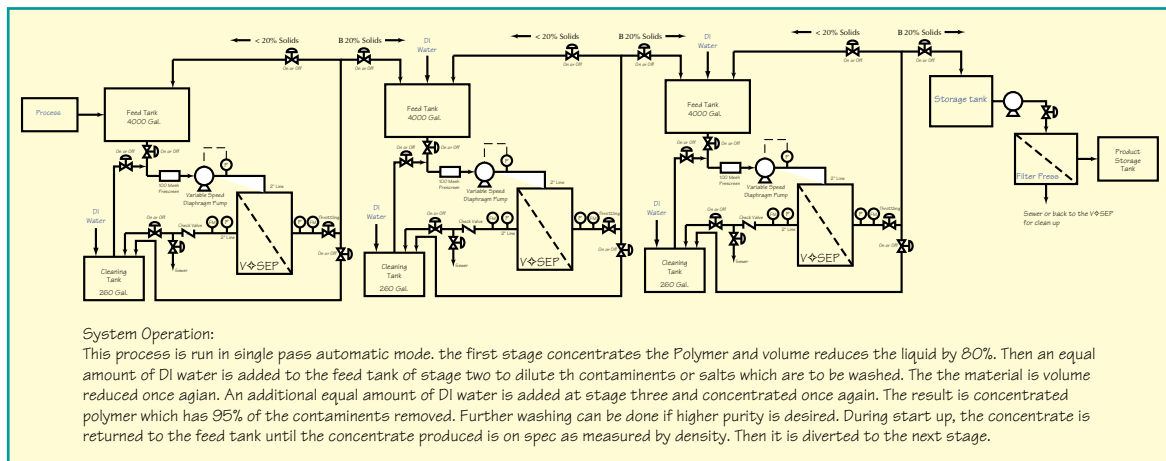
The process flow diagram below illustrates a common configuration for polymer diafiltration. In the case shown, the polymer is first dewatered to about 1/3 of the gel point of the material which is approximately where optimum diafiltration can occur. Then after the volume reduction, the concentrated material is continuously diluted with clean water and filtered. The reject macromolecules from this go on to a third stage where the process repeats.

This process could continue to infinity. In this case, a two stage washing process is able to reduce the salt contaminants by 99.5%. In all cases, a material balance study must be performed along with pilot testing to confirm theoretical results. The objective is to determine the optimum process design that will result in an efficient and economical system.





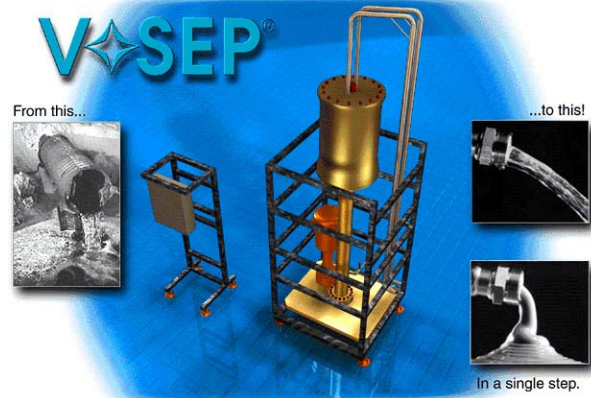
Multiple Stage Diafiltration Simplified P&ID Drawing



Company Info

New Logic Research 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.

New Logic offers a strong engineering staff to assist customers in the design, development, and testing of their filtration systems. After outgrowing two previous locations in the last ten years, New Logic is now located in a 40,000 square foot manufacturing building in Emeryville. The plant has extensive equipment and machinery for manufacturing nearly all the V◇SEP parts. Manufacturing, assembly, and testing of all equipment takes place at this site. Systems and procedures are in place and geared towards high standards of quality control and have met the acceptance criteria of stringent applications such as nuclear waste processing.



For more information about V◇SEP contact:

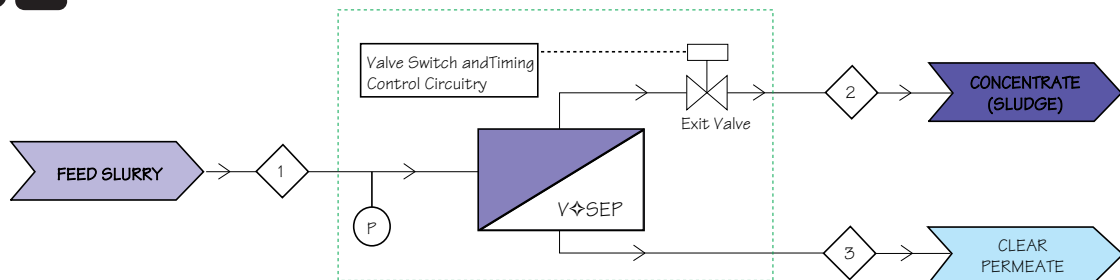
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**NEW LOGIC'S FILTRATION SYSTEM
 MEMBRANES THAT CAN DO THIS**

- ✓ Discriminating Molecular Separation
 - ✓ Create a high solids concentrate in a **single pass**
 - ✓ Separate any Liquid / Solid stream that flows
 - ✓ Recovery of valuable chemical products
 - ✓ Reduce operating costs and plant size
 - ✓ Replace expensive, traditional processes*
- (*Flocculation, Sedimentation, Vacuum Filtration, Centrifugation, Evaporation, Etc.)

CE



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