NEW LOGIC RESEARCH

Case Study

Using Vibrating Membranes to Treat Oily Wastewater from a Waste Hauling Facility

V✧SEP Membrane System installed at a major manufacturing facility for oily water filtration.

Overview

A unique membrane filtration system has been installed at several major waste oil hauling operations and manufacturing plants that handle or produce oily wastewater. The system manufactured by New Logic, of Emeryville California near San Francisco, is also being used to process used crankcase waste oil and produce filtrate that can be sold as a higher value bunker oil. The V✧SEP, (Vibratory Shear Enhanced Process), system uses a membrane module with special construction for service with high temperature solvents and waste oils and is able to recover up to 90% of the oily wastewater as clean water. The use of high temperature polymeric membranes has many significant advantages over the conventional methods of oily water treatment. There are dozens of methods used for oil water separation. Each technique has advantages. No one technique is suitable for all situations. V✧SEP has very good overall usefulness. Membranes have the advantage of being simple efficient separating devices to hold back oil, grease, metals, BOD, and COD. They can provide clear permeate which can be sewered or re-used.

Membranes

Membrane separation technology has been around for many years. Initially, the use of membranes was isolated to a laboratory scale. However, improvements over the past twenty years have made it possible to use membranes on an industrial level. A membrane is simply a synthetic barrier, which prevents the transport of certain components based on various characteristics. Membranes are very diverse in their nature with the one unifying theme to separate. Membranes can be liquid or solid, homogeneous or heterogeneous and can range in thickness. They can be manufactured to be electrically neutral, positive, negative or bipolar. These different characteristics enable membranes to perform many different separations from reverse osmosis to micro-filtration. There are four main categories of membrane filtration. These are determined by the Pore size or Molecular Weight Cut off

Filtration Type	Particle Size	Molecular Weight
Reverse Osmosis	≤ 0.001 µm	≤ 100 Dalton
Nanofiltration	0.001-0.01 µm	100 - 1000 Dalton
Ultrafiltration	0.01-0.1 µm	1000-500,000 Dalton
Microfiltration	≥ 0.1 µm	≥ 500,000 Dalton

Reverse Osmosis Membranes

The first category of membranes is for Reverse Osmosis. These are the tightest membranes for separating materials. They are generally rated on the % of salts that they can remove from a feed stream. However, they can also be specified by Molecular Weight cutoff. Usually, the rejection of NaCl will be greater than 95% in order to be classed as an RO membrane. The molecular weight cutoff is shown in the table to the left. An example of their use would be for filtering seawater in order to remove the salt. They are also used to remove color, fragrance and flavor from water streams. Reverse Osmosis membranes don't have structural pores. Filtration occurs as ionic species are able to diffuse their way through the membrane itself.

Nanofiltration Membranes

A great deal of recent research has led to the improvement of membranes in the range of Nanofiltration. As the name suggests, these membranes are used to separate materials on the order of nanometers. These membranes are not usually rated based on their pore size because the pores are very small and difficult to measure accurately. Instead they are rated based on the approximate molecular weight of the components that they reject or the % of salts that they can remove from a stream. These membranes are used predominately for wastewater treatment but they are also used to concentrate material that has a wide range of particle sizes.

Ultrafiltration Membranes

Conventional Ultrafiltration membranes are composed of some type of polymer material with pores ranging from a little less than 0.01 μm to 0.1 μm. These membranes are used for many different separations including oily wastewater treatment, protein concentration, colloidal silica concentration and for the treatment of various wastewaters in the Pulp & Paper industry.

Microfiltration Membranes

These membranes tend to be porous, with pores greater than 0.1μm. These types of membranes are used to separate larger particulate matter from a liquid phase. Some examples would be coarse minerals or paint particles, which need to be concentrated from an aqueous solution.

Oily Wastewater

Oil/Water separation covers a broad spectrum of industrial process operations. There are many techniques employed depending on the situation. This summary will address those separations, which are suited to the V✧SEPs membrane technology. The oily wastewater application can be broken down into categories determined by the type of user and the oil/ water separation desired.

Types of V✧SEP Oily Wastewater customers:

Barge/Bilge Water from marine operations
Manufacturing where oily water is a waste product
Waste haulers & recyclers

There is a saying: "Oil and Water don't mix". This is true, but they can exist as an emulsion. Oil is not soluble in water but it can exist evenly dispersed as globules in water. The concentration of these globules is a function of mixing or stirring. If allowed to stand the emulsion will separate because oil is lighter than water, although, some amount of oil globules will remain in the water. Another interesting fact is that this emulsion can exist two ways. If the concentration of Oil is less than 50%, the water will be the suspension fluid and the oil will be the globule. A phase transition occurs if the oil content is more than 50%. When this happens, the oil is the suspension fluid and the water forms globules. For this reason, hydrophilic membrane separations will be possible only when the oil content is less than 50%.

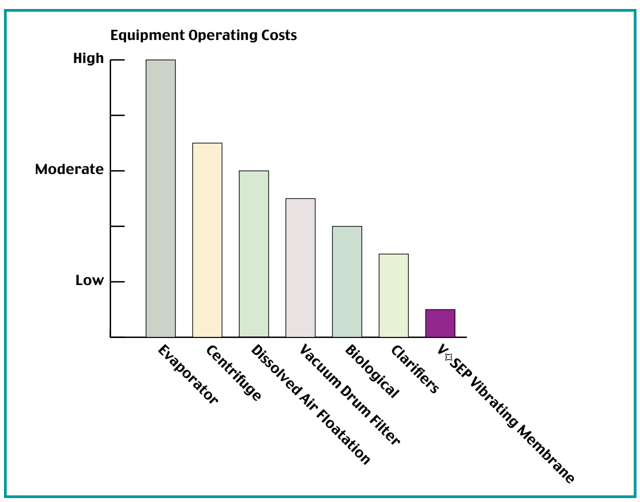
Commercial Uses

Sometimes mixing of oil and water is intentional and some times it is an unavoidable necessity. The following are instances of oil water mixtures:

Produced Water: Water is injected into drilling shafts to displace oil. Barge/Bilge Water: Wash down cleaning operations contaminated by oil. Machining Coolant: Oil mixed with water acts as a lubricant to reduce tool wear. Washwater with Degreaser: Fluid used for cleaning oily or greasy parts. Lubricant Manufacturing Wastewater

Methods used for Oil Water Separation

Centrifuge
Rotary Drum Vacuum Filter
Dissolved Air Flotation (DAF)
Slope Plate Clarifiers
Biological Treatment
Evaporators
Gravity Separating Devices



Relative Operating Cost comparisons of various technologies for treating oily wastewater

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Comparisons of Oil Water Separation Technologies

Centrifuge: Uses large horsepower motors and because of the number of moving parts is subject to high maintenance. While centrifuges are effective at removing suspended solids, they do not account for dissolved solids and heavy metal species in solution. The effluent from a centrifuge would need further treatment prior to disposal.

Rotary Drum Vacuum Filter: Quite effective at rejecting large solids. sometimes filtrate must be sent back around to get all of the smaller particles. Usually employs coarse filtration. Vacuum filters require large floor areas and have high capital costs

Dissolved Air Flotation (DAF): Large tanks where air is bubbled into the bottom and with the use of flocculants, solids are floated to the top and skimmed off. A very large tank is required due to the residence time required. Also chemical addition is a daily if not hourly process and is a significant operating cost.

Slope Plate Clarifiers: Cheap and easy to use. The process relies on gravity to drop out heavy solids. Here again colloidal materials with small mass and dissolved constituents do not settle. Sometimes it is used in conjunction with flocculation chemicals. These chemicals have limited effect in dropping out heavy metals, BOD, and COD.

Biological Treatment: This process relies on biological activity to digest the solids in the wastewater. The problem is that the system is extremely temperature and pH sensitive. Also loading must be done at a set rate. The operation of this kind of system usually requires a very skilled operator. It also can take up a lot of floor space due to the amount of residence time required for the bugs to digest the materials.

Evaporators: Can reduce wastewater to dry solids that can be landfilled. Of course water re-use is not possible. Evaporators have very high capital costs and consume huge amounts of energy even for the most efficient models.

V✧SEP

Able to produce drinking water quality filtrate from any wastewater. Extremely energy efficient and the vertical design allows for a very small footprint. Does not require pre-treatment or post-treatment for that matter. Wide range of membranes available allow for precise separations based on the process objectives. There is no chemical addition required except for periodical membrane cleaning.

Suitability of V✧SEP for Oily Wastewater

As with other waste streams, volume reduction is the goal. Hauling and disposal costs are king. Wastewaters normally have very strict sewering rules and surcharges are attached to anything that is sewered. Since Oil is normally limited to 100 ppm, oily wastewaters cannot be sewered and must be taken care of in other ways. Oil can also not be landfilled as long as it is a liquid. Therefore, disposal of oily wastewater is an expensive operation. Volume reduction of the oily wastewater will reduce the treatment costs to dispose of the material. There are also many types of membrane solutions for oil water separation. A common membrane device used is a tubular membrane system. One common problem with Tubular Membrane Systems is the permeate quality. V✧SEP can offer competitive installed costs along with RO quality permeate requiring less post treatment.

Concentration Polarization is the main limiting factor to membrane filtration with oily wastewaters. Therefore the existence of a boundary layer of highly concentrated oil and solids next to the membrane surface must be eliminated. Spiral membranes employ crossflow and fluid velocity to accomplish this. Tubular membranes use the same technique with greater efficiency. None of these has the degree of efficiency of the vibrating membrane surface of V✧SEP which can use both high crossflow velocities

Typical Sewer Discharge Limits:

Nickel	4.1 mg/L
Mercury	0.0015 mg/L
Lead	1.1 mg/L
Zinc	12.7 mg/L
Silver	1.2 mg/L
Copper	4.2 mg/L
Chromium	5.0 mg/L
Cadmium	0.43 mg/L
Arsenic	0.57 mg/L
Cyanide	0.50 mg/L
Oil & Grease	100.0 mg/L

V✧SEP Filtration Results

Process	Membrane	% Recovery	Initial % Solids	Final % Solids	Flux (GFD)*
Oily Wastewater	Nanofiltration	80%	0.07%	0.81%	135
Oily Wastewater	70k mwco UF	60%	0.15%	1.47%	100
Oily Wastewater	0.1 µm MF	85%	6.15%	9.47%	80
Lubricant Wastewater	100k mwco UF	60%	10.33%	25.82%	68
Machine Coolant	7k mwco UF	75%	2.89%	13.82%	65
Oily Wastewater	Nanofiltration	90%	0.61%	6.64%	65
Lubricant Wastewater	Nanofiltration	75%	2.37%	37.02%	62
Oily Wastewater	Nanofiltration	80%	1.01%	20.31%	50
Oily Wastewater	7k mwco UF	75%	0.96%	7.42%	48
Washwater Degreaser	Reverse Osmosis	60%	3.02%	9.59%	45
Oily Wastewater	Nanofiltration	80%	1.83%	11.31%	42
Produced Water	Nanofiltration	90%	5.23%	10.66%	40
Oily Wastewater	Nanofiltration	78%	2.15%	9.97%	38
Oily Wastewater	Nanofiltration	85%	3.48%	22.52%	38
Produced Water/Silt	100k mwco UF	70%	22.69%	84.19%	30
Oily Wastewater	5k mwco UF	75%	0.15%	0.47%	22
Oily Wastewater	Nanofiltration	80%	1.45%	9.28%	20
Averages		76%	3.80%	16.52%	56

* GFD (Gallons per sqare foot per day of membrane area)

as well as high vibrational energy at the membrane surface which is oscillating back and forth 55 times per second. Performance comparisons based on GFD of permeate flow is difficult because there are so many variables to consider. If all things are equal and the comparison is apples and apples, V✧SEP will outperform the other membrane-based technologies. Permeate flow rates will vary depending on the initial concentration of oil and other materials in the feed material as well as the % recovery which is being achieved.

Compact Design

The V✧SEP Machine 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 separations systems. The V✧SEP does require up to 17' in ceiling clearance. In most industrial applications ceiling clearance is ample, it is floor space which is limited.

Benefits of V✧SEP Compact Modular 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 systems or as single pass
5] Can be "chain linked" to an any number depending on demand.
6] More units can be installed as production grows.

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 completed systems ready to use. 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!!

Typical V✧SEP Performance:

	Feed	Permeate
Nickel	60 mg/L	ND
Lead	5 mg/L	ND
Zinc	100 mg/L	ND
Copper	70mg/L	ND
BOD	19,100 mg/L	7,640 mg/L
TOC	15,000 mg/L	50 mg/L

Effects of Temperature

Temperature needs to be considered with regard to design. Temperature can be used to increase filtration performance. A stream that appears to be too expensive to filter at 25°C may be well within the budget for a project at 40 or 50°C even though you have a cost associated with heating the feed. The reason is because increased temperature decreases the viscosity of the liquid and enables the material to flow through the membrane faster. It also makes it possible to reach a higher endpoint solids because generally the material remains more fluid at a higher temperature. As many streams are water-based, the following table provides the viscosity correction factors for water at various temperatures. The

Interesting Facts:

Oil waste ending up in sewers and dumps each year is equal to 25 times the amount of crude oil spilled in the Exxon Valdez accident.

following empirical relationships between viscosity and temperature are based on measurements taken with viscometers calibrated with water at 20°C.

0°C to 20°C
$log10hT = ((1301)/(998.333+8.1855(T-20)+0.00585(T-20)^2)-1.30233$

20°C to 100°C
$log10(hT/h20) = ((1.3272(20-T)-0.001053(T-20)^2)/(T+105))$

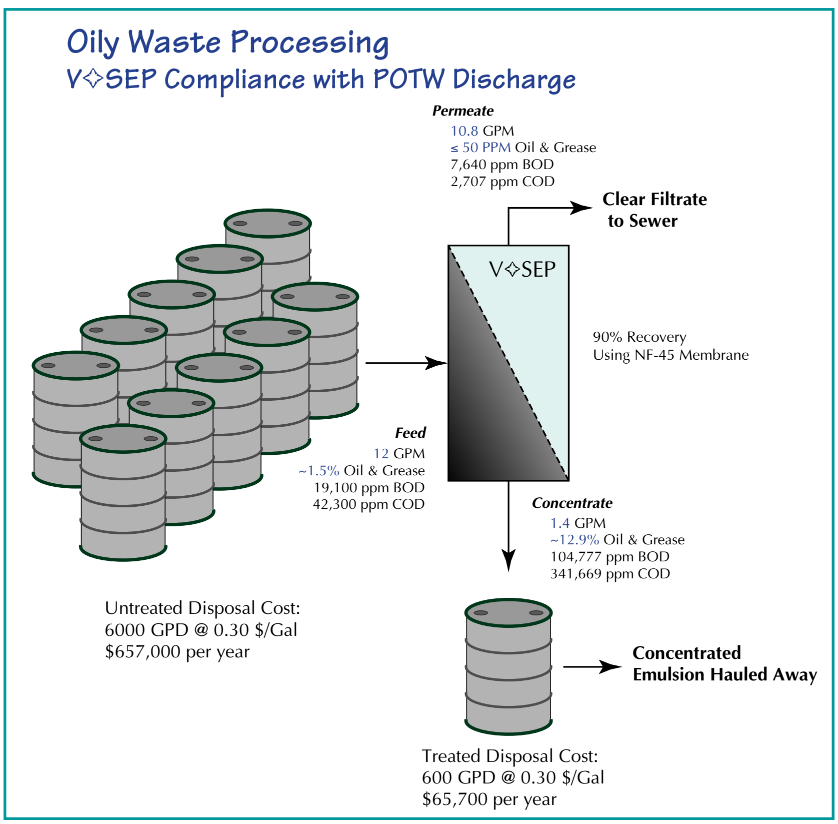
For example, if a wastewater stream had a flux of 110 GFD at 25°C and you wanted to know what the flux would be at 50°C then you could set up the following ratio to give you an estimate based on the change in viscosity.

(h @25°C)(Flux @25°C) = (h@50°C)(Flux@50°C)
(0.8904)(110) = x(0.5468)
x = 179 GFD (@50°C)

These types of calculations can also be completed for other materials given the viscosity versus temperature relationships for the feed liquid. As seen in the above example, doubling the temperature nearly doubles the flow rate. The result of this is that it requires about half as much equipment to do a filtration separation at 50ºC as it would at 25ºC. This means lower capital cost as well as lower operating costs. The V✧SEP has been designed to withstand temperatures of up to 120ºC

Volume Reduction

With Oily wastewater, hauling for disposal is the conventional method of remediation. Since hauling costs can be very expensive, reducing the volume that needs to be hauled can have a significant effect on operating costs. V✧SEP is capable of volume reducing wastewaters by up to 98% leaving a small amount to be hauled and clean water that can be sewered or reused in the process. The recovery ratio is the amount of liquid, which is recovered as clean, permeate from the feed flow. In other words, it is the ratio of liquid that passes through the membrane versus what is fed to the membrane. This is usually a critical factor for membrane filtration because for a product dewatering or wastewater application, a person is generally looking to remove as much of the water as possible. There are two costs of higher recoveries: lower flux rates and degraded permeate quality. These effects are especially prevalent when you are reaching into the high 90% range. The average flux degrades because the feed side solids increase as you recover more and more of the water. In our filter pack, the feed enters through a pipe in the top of the filter module and flows in a serpentine pattern throughout the pack. The higher recovery does not affect the flux at the top of the filter pack because that material is almost always at the same concentration given a consistent feed. However, the material at the bottom of the filter pack will flux slower because it contains less water for removal and more solids to impede the flow of liquid through the membrane. The average flux is a time weighted average across the entire filter pack. If the flux at the bottom of the pack becomes slower then it will in turn lower the overall average flux. The permeate quality degradation occurs in

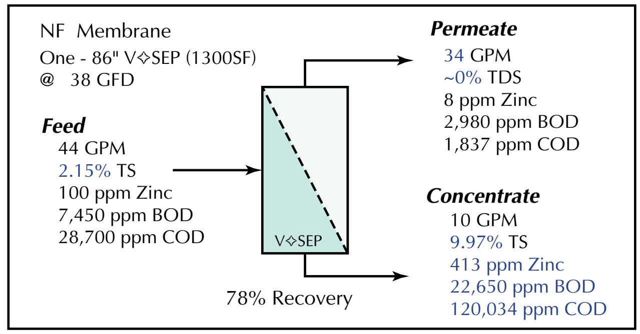


the tighter ultrafiltration, nano-filtration and RO membranes where there is rejection number based on % of molecules or ions in the feed. Again as you remove more of the water, the concentration on the feed side will increase and given that the rejection of the membrane remains constant less and less of the feed solids will be rejected. Those solids will instead be passed through the membrane into the permeate. For example, a 90% NaCl reject membrane will still be rejecting 90% of the dissolved solids at perhaps a 60% recovery. However, beyond that recovery the permeate quality will slowly deteriorate because the feed side solids are increasing. Since 10% of the feed side solids pass through the membrane (by definition a 90% reject membrane), the amount of material which passes through the membrane will increase. This material pollutes the permeate. When the recovery is nearly the same as the rejection then the system behaves as if there is no membrane. Therefore, it is important to not only identify the membrane and the desired recovery but also consider the economic tradeoff between permeate quality and recovery.

Process Conditions

A process schematic for treatment of a typical oily wastewater process using a V✧SEP system is presented in the figure to the right. When the residual oily wastewater has been settled so that oil and water can separate naturally, the result is a process effluent, at 1.5 to 2% by weight total solids (TS). This process effluent is normally sent to a multi-train chemical treatment step by a filter press or a dryer or an evaporator in order to concentrate the solids to 60 to 65% by weight. As you can see in the diagram, the addition of V✧SEP to concentrate the process effluent improves the process efficiency. The permeate can be reused in the process or discharged.

The oily wastewater is fed to the V✧SEP treatment system at a rate of 44 gpm and a pressure of 250 psig. One industrial scale V✧SEP unit, using nano-filtration membrane is used to treat the process effluent. The produced concentrated stream at a flow rate of 10 gpm and a solids concentration of 10% TS is sent to a coalescer and stored for hauling. V✧SEP generates a permeate stream of about 34 gpm which is recycled to the process or discharged to the sewer. The permeate concentration is reduced to ~ 1 mg/L of total suspended

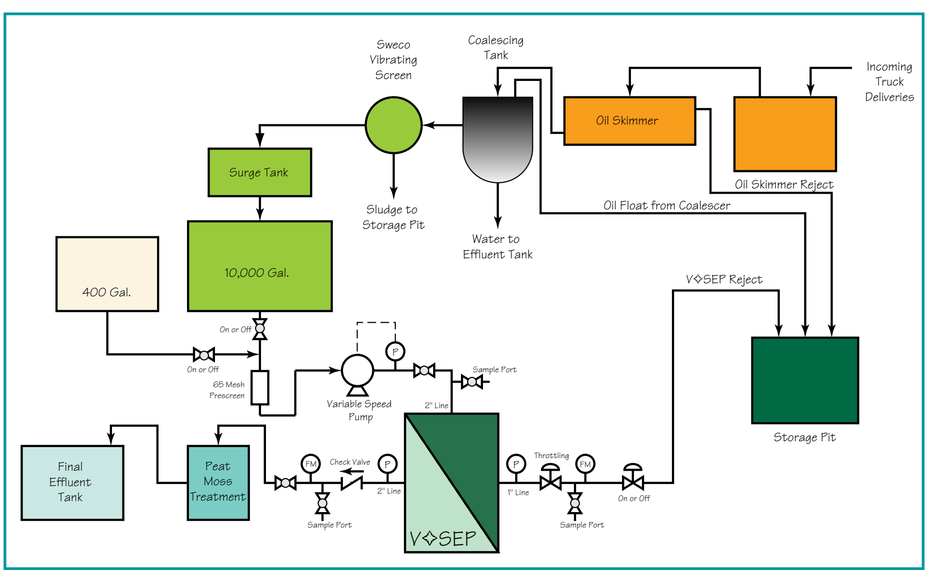


Important Note: The Feed material is always different. The illustration above shows typical performance

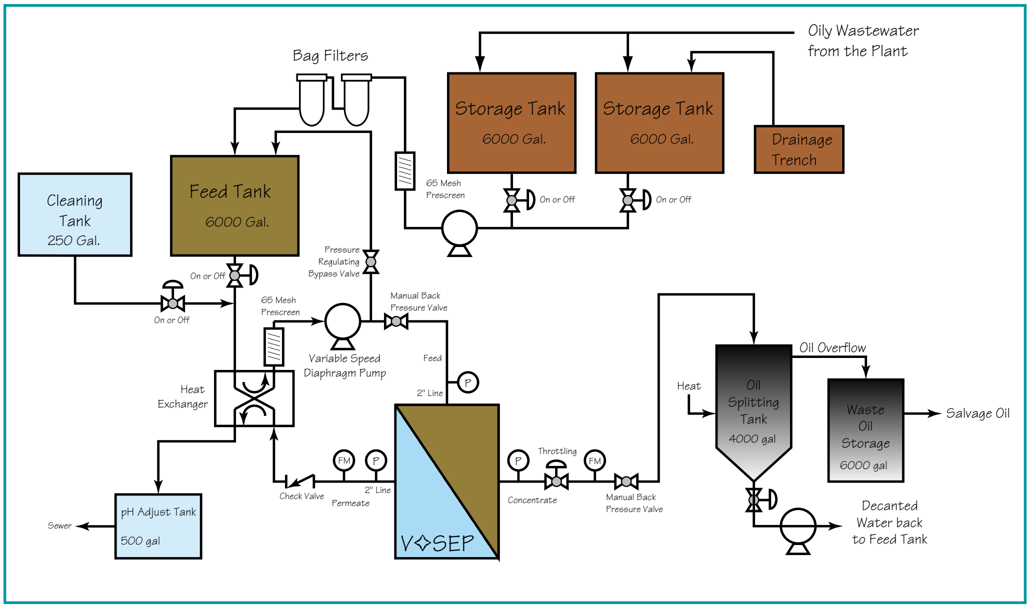
One Case Study showing the relative BOD and COD reductions possible with V✧SEP

solids (TSS), and a low level of total dissolved solids (TDS), all well below the design requirements for process recycling or discharge. Membrane selection is based on material compatibility, flux rates (capacity) and concentration requirements. In this example, the TSS reduction is over 99% while the oily waste is concentrated from a starting feed of 1.5-2% to a final concentrate of 10% by weight. The permeate quality from the V✧SEP can be controlled though laboratory selection of membrane materials available to fit the application parameters.

Successful pilot tests have been conducted at New Logic for many kinds of oily wastewater treatment. Depending on process temperatures, membrane selection and the requirement for solids concentration or BOD/COD removal for effluent streams, the permeate flux rate in the V✧SEP can range from 15 to over 150 gallons per day per square foot (GFD).



Case Study

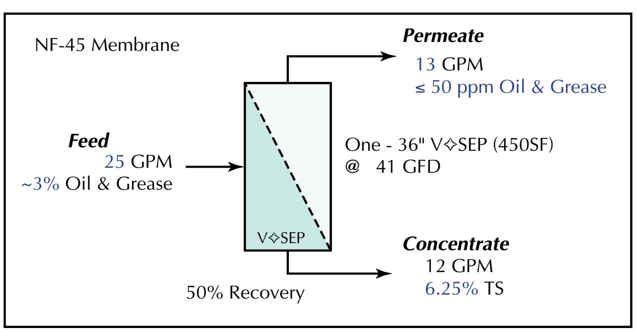


Typical Case Study for a manufacturing facility and how V◇SEP is used

Typical makeup of Oily Wastewater:

Common Name	Content
Water	~98.5%
Oil & Grease	1.50%
Zinc	100 ppm
Lead	10 ppm
Copper	70 ppm
Nickel	60 ppm
TSS	250 ppm

Dissolved heavy metals must be removed using filtration prior to sewering



Second Case Study Block Diagram for V◇SEP

Economic Value

New Logic's V◇SEP system provides an alternative approach for oily wastewater treatment applications. In a single operation step, V◇SEP will provide concentrated oil sludge and also reduce BOD, COD, TSS, TDS and color to provide a high quality permeate stream for discharge or reuse in the process. In many applications, the addition of V◇SEP will eliminate conventional treatment process requirements and technologies without chemical treatment demands. The justification for the use of V◇SEP treatment system in your process is determined through analysis of the system cost and benefits including:

Reduction of solids from discharge stream and the associated treatment cost.
Reduction of BOD, COD, TSS, TDS and color for the effluent stream.
Provision of high quality water for reintroduction into the process.
Offset fresh water demands and pretreatment cost.
Retain heat in recycled process water as a possible method to reduce energy requirements.
Elimination of biological growth, and odor in effluent.
Simplify effluent treatment with a compact, low energy system.

Your New Logic Sales engineer can assist with economics analysis for your project and can demonstrate operating cost savings and Return on Investment calculations.

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The Table below shows the potential operating cost savings from the installation of one V✧SEP module as currently configured.

Summary

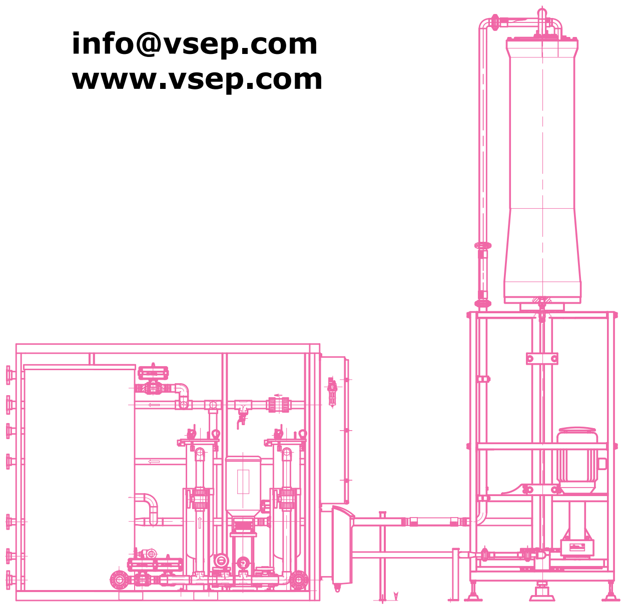
New Logic Research has supplied V✧SEP separation technology successfully into many industrial processes. Manufacturing plants' as well as the oil waste hauling industries' efforts to meet environmental regulations will be enhanced with the utilization of membrane filtration combined with "Vibratory Shear Enhanced Processing". The availability of new membrane materials and V✧SEP technology make it possible to treat the more difficult streams with very successful, economic results.

Contact a New Logic representative to develop an economic analysis and justification for the V✧SEP in your system. For additional information and potential application of this technology to your process, visit New Logic's Website @ http:/www.vsep.com or contact New Logic, 1295 Sixty Seventh Street, Emeryville, CA 94608, Phone: 510-655-7305, Fax: 510-655-7307, E-mail: info@vsep.com.

For more information, contact:

New Logic Research
1295 67th Street
Emeryville, CA 94608 USA
510-655-7305
510-655-7307 fax

info@vsep.com
www.vsep.com



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.)

V✧SEP ... *A New Standard in Rapid Separation*