NEW LOGIC RESEARCH

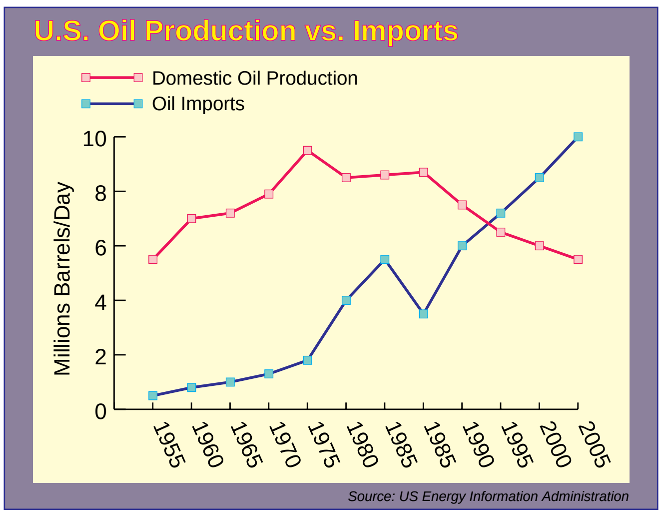
# Application Note

## V✧SEP Filtration for Ethanol Recovery

A cost-effective and energy efficient processing solution

### Overview

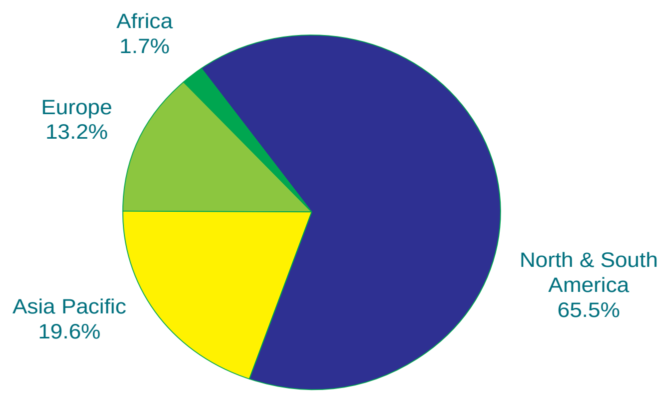
As the world searches for fuel alternatives to gasoline, a clear candidate to lead the way has emerged, *Ethanol*. Ethanol production for use as a fuel additive (or to be used directly as a fuel source) has grown in popularity due to governmental regulations and in some cases economic incentives. Both regulations and incentives seem to be based on environmental concerns as well as a desire to reduce the oil dependency of our industries and our everyday lives.




**As domestic production of Crude Oil has steadily decreased in the United States, reliance on foreign sources of Oil has increased**

> **Ethanol is a Clean Energy Source**
>
> Ethanol's use as an oxygenate increased with the passage of the Clean Air Act Amendments of 1990, which require the addition of oxygenates to gasoline in the nation's most polluted areas. Ethanol, which contains approximately 35% oxygen, enhances combustion and therefore contributes to a more efficient burn of gasoline, reducing carbon monoxide emissions, a contributor to harmful ozone formation, by as much as 30%.
>
> Ethanol's popularity surged to an all-time high in 2000, achieving monthly and annual production records. The U.S. fuel ethanol industry today boasts more than 2 billion gallons of annual production capacity, and will continue to break new records in 2001.

While the leading Ethanol producer in the world is Brazil, the United States is a close second. If the state of California bans all MTBE in 2003 as a fuel additive (as is currently required) ethanol demand will rise dramatically and the United States will overtake Brazil as the leading producer of Ethanol. MTBE, like ethanol, is an oxygenate which helps gasoline to burn more cleanly. Currently in the United States, tax incentives are used in order to improve the security of liquid fuel supplies such as Ethanol. The government provided tax incentives to promote the use of Ethanol in gasoline thus creating jobs and businesses in rural areas. As a result of these federal and state incentives, annual fuel ethanol production increased to approximately 1.5 billion gallons in the United States by 1995; current annual domestic ethanol sales are over $1 billion and are expected to increase. Roughly 10% of the total gasoline supply in the United States is now gasohol, a blend of 10% ethanol with 90% gasoline.




**Worldwide Ethanol Production**

**Brazil and the United States are the leading producers of Fuel Ethanol**

In Europe and other parts of the world, high gasoline prices and an urgency to find cleaner fuel additives has increased the interest in Ethanol production as well, however the quantity of production still lags far behind Brazil and the United States. The primary reason for this is said to be a lack of a single biomass source that would help standardize the industry, although other economic hurdles do still exist as well. Asia's three main countries involved in the development of Ethanol production are China, Thailand and India.

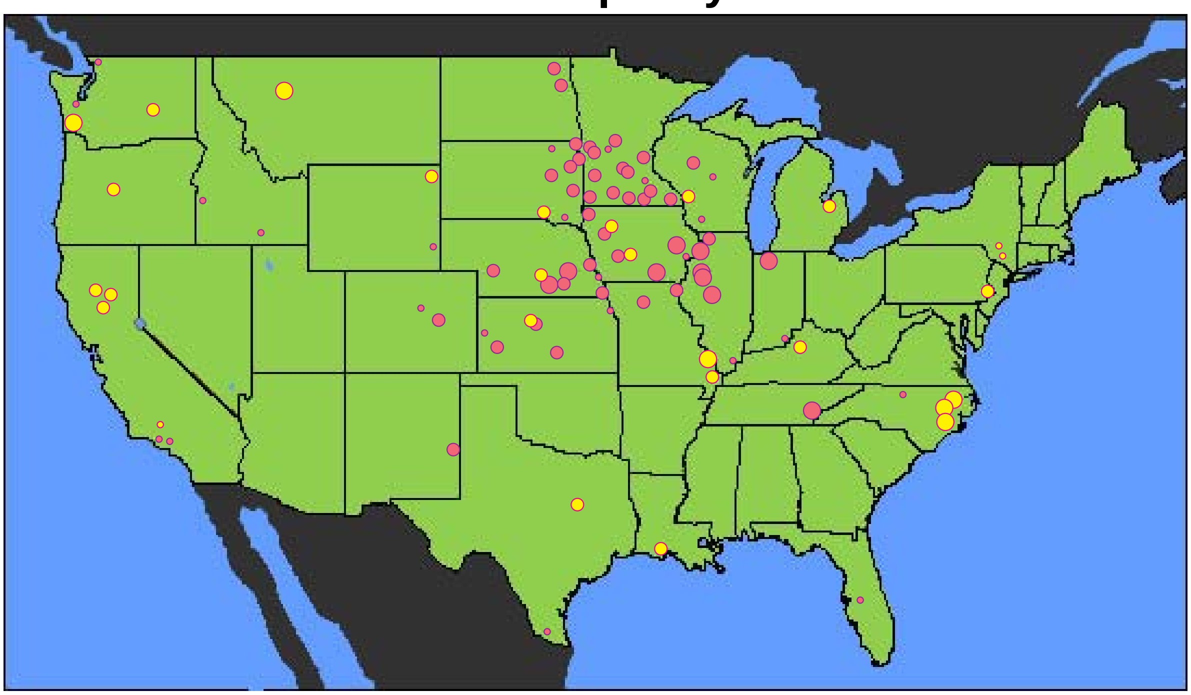
### Background

Ethanol is produced by the fermentation of monosaccharides such as glucose and fructose. The monosaccharides are typically formed through the hydrolysis of any number of biomass options. The biomass source for Ethanol production varies depending primarily on local economics and resources. This can be considered an advantage in that regional development of fuel production facilities can optimize for the economics and resources of their own particular surroundings. The two largest producers of Ethanol, Brazil and the United States, use biomass sources that are high in carbohydrate content. Other cellulose feed sources are possible as well, such as grass or woodchips.

| Cellulosic Sources of Ethanol | |
|---|---|
| Bagasse | Corn Stover |
| Forest Residues | Yard Clippings |
| Rice Hulls | Wood Waste |
| Sawdust | MSW |
| Pulp & Paper Sludge | Switch Grass |
| Rice Straw | Fast Growing Trees |

The draw back in using cellulose material as opposed to carbohydrate material is the cost of converting the biomass source to a monomeric sugar that can be easily converted to Ethanol through fermentation. Research is presently under way to develop better enzymes for lingocellulosic fermentation.

## U.S. Ethanol Production Capacity



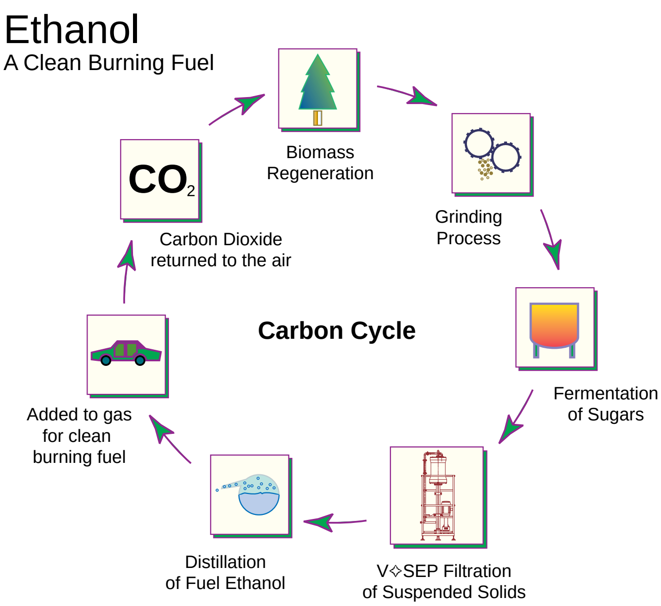
Operating or near completion (2001)
Total Capacity = 2220 million gal/yr
- Less than 10 million gal/yr
- 10-40 million gal/yr
- Greater than 40 million gal/yr

Planned or under development (2001)
Total Capacity = 993 million gal/yr
- Less than 10 million gal/yr
- 10-40 million gal/yr
- Greater than 40 million gal/yr

Regardless of the biomass source, the basic process of Ethanol production or recovery is the same. The process consists of three important steps, and in some cases surrounding processes in order to optimize the overall process. The three main steps that are always present are in order;

Hydrolysis → Fermentation → Distillation.

In some cases the first two steps, hydrolysis and fermentation are carried out simultaneously. In all cases there is a solid residue as a byproduct as well as an aqueous stream left over from the distillation process.




Removal of the solids from the aqueous stream can take place before or after distillation. Removal prior to distillation has the benefit of keeping the distillation equipment clean and free of solid residue build up. The aqueous stream can then be treated with simple evaporation technology.

**Hydrolysis**

The two primary forms of hydrolysis used in Ethanol production are categorized as enzymatic and acidic. Enzymatic hydrolysis uses organisms and in some cases synthetic enzymes specifically designed to convert carbohydrates to monosaccharides. Production facilities using carbohydrate rich biomass typically use enzymatic hydrolysis. Acidic hydrolysis is typically used for cellulose rich biomass, though not exclusively. Converting cellulosic material is more difficult then converting carbohydrates to monosaccharides.

**Fermentation**

Fermentation is carried out in a reactor with yeast components that convert the glucose or other monosaccharides to Ethanol. The fermentation process breaks down 1 part sugar into 2 parts Ethanol and 2 parts Carbon Dioxide:

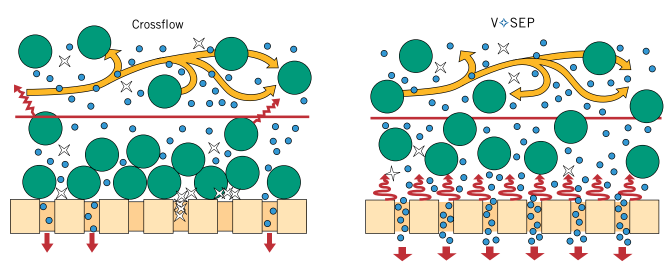
$$C_6H_{12}O_6 \;\blacksquare\;\blacksquare\;\blacksquare\; 2\,CH_3CH_2OH + 2\,CO_2$$

**Distillation**

The Ethanol is removed from the water and solids by taking advantage of its lower boiling point. The Ethanol at this stage is typically 96% pure (4% water). In order to create anhydrous Ethanol, a secondary step is required. The water and solids left behind are often called "stillage." The stillage can then be concentrated and used for many different purposes such as boiler fuel.

**V✧SEP Use In Solids Removal**

Removing the solids from the system can be very difficult and costly. The leftover biomass from the Ethanol production must be removed from the aqueous stream in order to have any value as incinerator fuel. V✧SEP is specifically designed to handle high solid liquid streams.



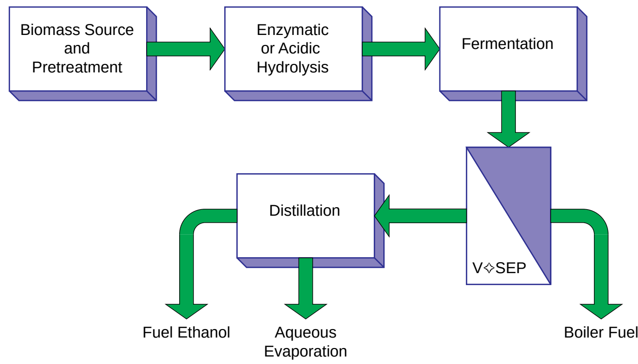

**V✧SEP Vibratory Shear Enhanced Process**

# Application Note

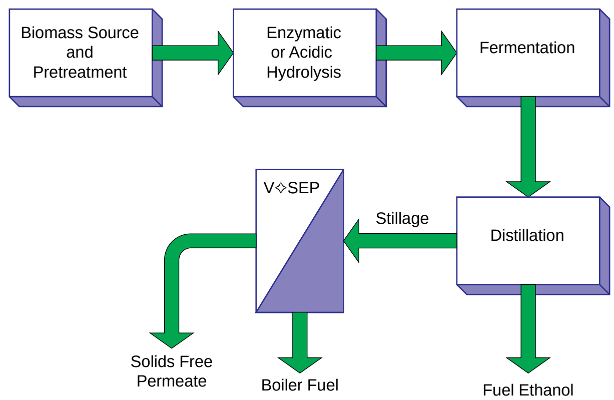
## Recent Case Study

With the help of Peder Wallentin of Nordcap, located in Goteburg, Sweden (http://www.nordcap.se), a study was arranged and completed at Lund University in Lund, Sweden (http://www.lu.se/lu/engindex.html). Lund University is Scandinavia's most complete University, and is considered the most advanced research organization in Sweden. At Lund University a method for efficient fermentation of wood fibers to produce bio-ethanol using specifically adapted yeast was developed. The study completed by Mats Galbe, Linda Pilcher and Christian Roslander of the Lund University Chemical Engineering Department also compared the use of V✧SEP with the use of a Decanter Centrifuge in removing solids after the fermentation process. The results proved to be crucial for the valuable bio-ethanol yield out of the process and were extremely favorable for V✧SEP. While the results of fiber concentration for both technologies were positive, the advantage of V✧SEP was clearly illustrated when examining the permeate that would go forward for distillation. The permeate from the V✧SEP was solids free, while the permeate from the Decanter Centrifuge was not. This test used a MF Teflon membrane with a pore size of 0.2 µm. Using the V✧SEP, the experiment was able to show a concentration in fiber solids from 3% to 18%; all the while generating a solids free permeate.

Using V✧SEP to remove the solids residue provides several key advantages over other technologies. First and foremost, the V✧SEP technology is the only system that can generate a totally solids free permeate prior to or after distillation and achieve a high level of solids concentration. In addition, the V✧SEP works with no chemical addition. The V✧SEP technology uses a Teflon membrane as the filtration media, a barrier technology for separation. When compared to other membrane technologies such as tubular membrane systems, V✧SEP has the advantage of being able to tolerate (and also concentrate) high levels of suspended solids. While tubular membrane system can handle higher levels of suspended solids than conventional spiral elements, they are unable to reach the same level of solids concentration as V✧SEP.




**Installation of V✧SEP prior to Distillation**




**Installation of V✧SEP on "Stillage"**

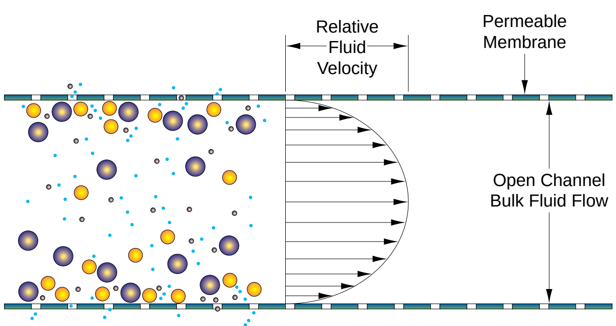
## Process Description

The overall process for Ethanol production would not change dramatically when adding V✧SEP to existing processes. When designing new installations, V✧SEP systems plug into larger systems with ease. V✧SEP would simply be installed between the fermentation and distillation portion of the overall process as illustrated in the following diagram, or after the distillation process in order to concentrate the stillage as shown in the second diagram above. The evaporation of the final aqueous stream may not be needed if a good use for the water can be found. The final treatment of the concentrated solids stream would depend on the end use. The most economical use of the solids removed from the process by V✧SEP would be that of incinerator/boiler feed material. Evaporation of the remaining water in the concentrated solids stream would be needed prior to feeding the material to the burner for incineration. The unique ability of V✧SEP to concentrate, and thus water reduce the original solid waste stream relieves the majority of the workload on the final evaporation step. This represents energy, and thus financial savings.

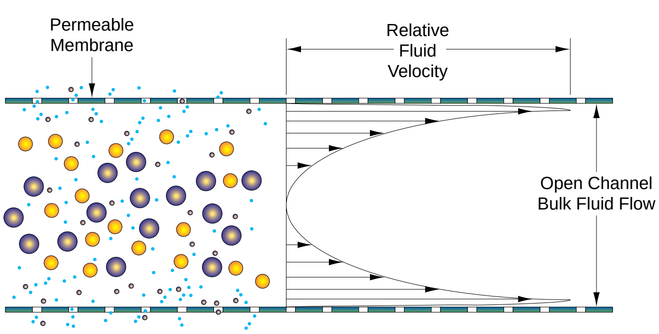
### Vibratory Shear Process

***NEW LOGIC*** developed V✧SEP to meet the needs of the industrial membrane market. Rather than simply preventing fouling with high velocity feed, V✧SEP reduced fouling by adding shear to the membrane surface through torsional vibration. This vibration produces shear waves that propagate sinusoidally from the surface of the membrane. As a result, this increase in the shear eliminates the stagnant boundary layer that exists with the more traditional membrane systems. See the diagram below for a visual comparison between V✧SEP and traditional crossflow filtration.

Tangential Flow Pattern in Crossflow Membrane Systems




Tangential Flow Pattern in Vibratory V✧SEP Membrane Systems




**The relative performance of V✧SEP modular Series i membrane filtration compared to crossflow**

## Ultra Filtration Membrane

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

**Typical V✧SEP membrane used for Ethanol Recovery**

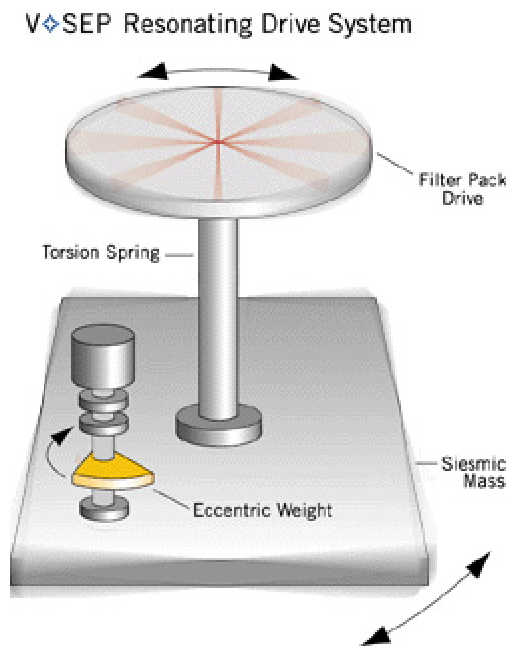
The industrial V✧SEP units contain several sheets of membrane which are arrayed as parallel disks separated by gaskets. The disk stack is contained within a fiberglass reinforced plastic cylinder (FRP). This entire assembly is vibrated in torsional oscillation, similar in principle to the agitation of a washing machine. The shear generated in a V✧SEP system is 150,000 s-1— ten times greater then that achieved in traditional crossflow systems. This high shear rate has been shown to significantly reduce or eliminate the susceptibility to fouling for many materials. The resistance to fouling can be enhanced by proper choice of membrane, where materials such as polypropylene, polysulfone, and polytetrafluoroetylhene (PTFE or Teflon) may be used.

Beyond the flow-induced shear of conventional crossflow filtration, V✧SEP can produce extremely high shear on the surface of the membrane. As mentioned above, this accomplished by the torsional vibration of a disk plate in resonance within a mass-spring-mass system. The membrane is attached to this plate and moves at an amplitude of 3/4" peak-to-peak displacement. The frequency at which the system vibrates is between 50 and 55 Hz. Much as in a laundry machine, the fluid in the stack remains fairly motionless creating a highly-focused shear zone at the surface of the membrane. Retained solids at the membrane surface are removed by the shear allowing for higher operating pressures and increased permeate rates. Feed pressure is provided by a pump, which consistently circulates new fluid to the filter.

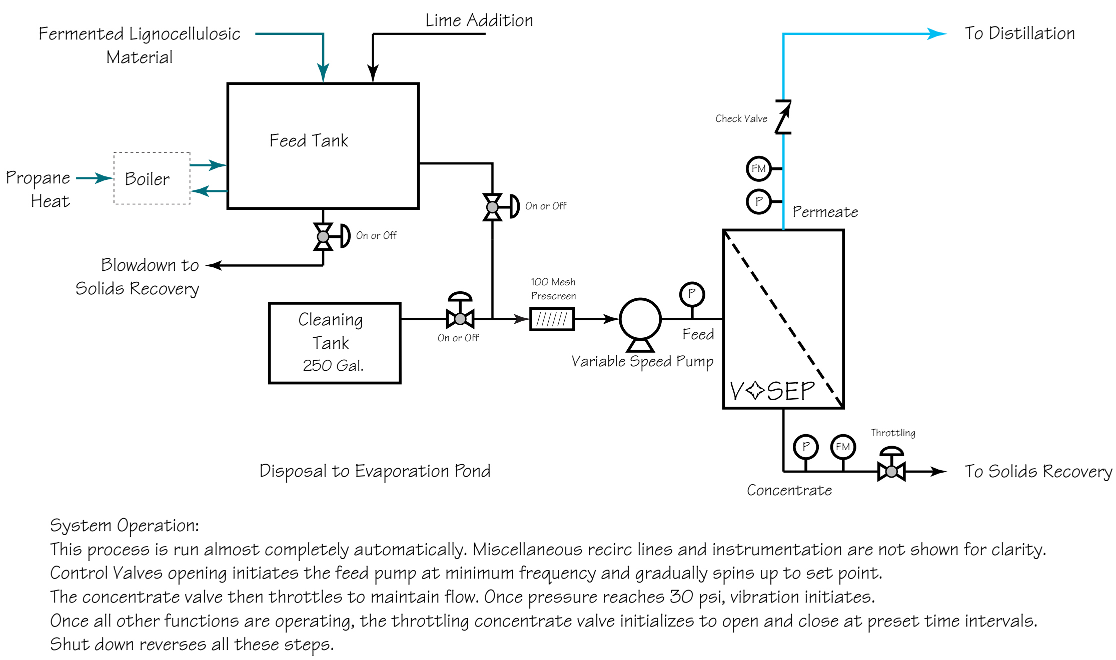
### System Components

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. 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, Ecentric Bearing, and Lower Pressure Plate.



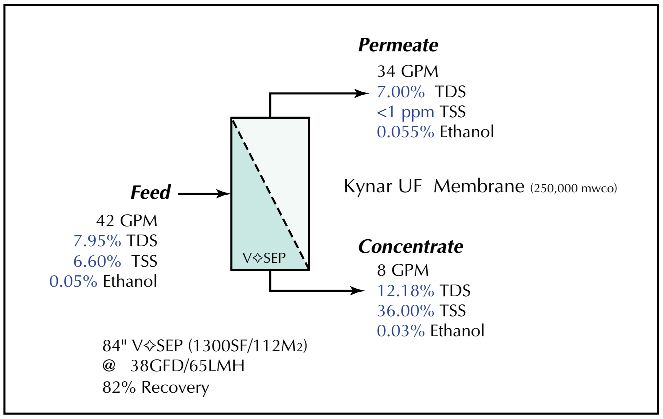

V✧SEP Drive System




Simplified V✧SEP P&ID Drawing

## Projected Throughput and Results

Based on the results of the Lund University study, a flux rate of 1.1 L/(min $m^2$) can be expected. This converts to a flux rate of roughly 38 GFD (gallons per square foot per day). An 84 inch filter pack with 1300 square feet of membrane would be expected to produce a permeate flow rate of 34.3 GPM, or 49,392 GPD. During this experiment, fiber solids were concentrated from an initial value of 3% to an ending value of 18%. This represents a concentration factor of 6x.




**Typical performance of a single V✧SEP modular Series i membrane filtration system**

## Economic Evaluation

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 dive 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.

**Table 1: Lignocellulosic Filtration - V✧SEP Operating Costs**

| Description | Description |
|---|---|
| V✧SEP System Power Consumption* | $ 7,180 |
| System Maintenance & Cleaning | $ 8,640 |
| | |
| | |
| | |
| | |

*based on 0.05 $/kW electricity cost

## Summary

Technological advances in membrane filtration systems and membranes have created an opportunity for the efficient and economical treatment of biomass dewatering. The "Vibratory Shear Enhanced Process" or V✧SEP™ developed by New Logic Research makes it possible to filter effluent streams using membrane technology. Unlike other chemical treatment systems where chemical flocculants are added which substantially increase the volume of waste material, V✧SEP volume reduces the material to a small percetage of its original. The dry solid can be used as fuel for a steam boiler.

V✧SEP represents a brand new cutting edge technology for dealing with this difficult liquid-solid separation. Agriculture has always been about recycling and reuse of nutrients. V✧SEP offers the best possible nutrient capture. V✧SEP outperforms decanter centrifuges, filter presses, and other conventional membrane systems when it comes to removing solids from feed waters to distillation columns. One of the challenges facing the Ethanol Recovery Industry is to reduce the cost of production to make it competitive with gasoline, even without government subsidies.

V✧SEP can provide a simple cost effective slipstream method of filtering ethanol laden biomass slurries. Use of V✧SEP can help towards making ethanol recovery more economical and profitable.

## Acknowledgments

- New Logic Research would like to thank the people of Norcap and Lund University for their continued interest and support in V✧SEP.
- Statistics for world ethanol production in 2001 taken from Dr. Christoph Berg's on line publication 'World Ethanol Production 2001.'

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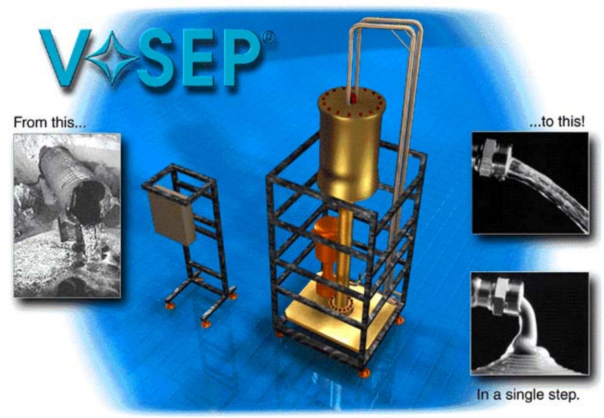


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## "Green" V✧SEP Applications

**Used Crankcase Oil Recycling**
**Oily Water Filtration**
**Coolant Recovery**
**HVOC Groundwater Remdiation**
**Acid Mine Drainage Treatment**
**Closed Circuit Water Recycling**
**Metal Plating Wastewater Compliance**
**Arsenic Removal from Wastewater**

### 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✧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✧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.

## 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.)

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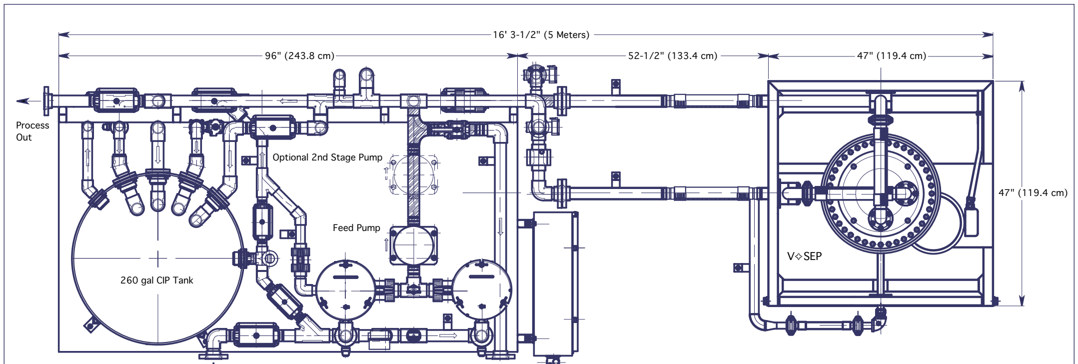


Typical Footprint Drawing for one 84" V✧SEP System

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