NEW LOGIC RESEARCH

Application Note

V✧SEP Filtration for Glycol Recovery

A cost-effective and energy efficient processing solution

Overview

New Logic has developed a unique membrane filtration system for treatment of all types of glycol based fluids. The objective is to recover as much glycol as possible and to remove contaminants and particulates added by usage. The process involves use of New Logic's proprietary V✧SEP (Vibratory Shear Enhanced Process) vibrating membrane filtration system.

Glycols have many uses including aircraft deicing, automobile anti-freeze, and manufacturing quenchants. They are also used in chemical processes to make resins, plasticizers, solvents, inks, surfactants, and many other consumer goods. In all cases, the V✧SEP process can be used to purify and recover the spent or processed glycol solution.

ADF (Aircraft Deicing Fluid) is applied hot by high pressure washing to melt and remove ice, snow, and frost fromthe airplane surfaces

Make up of Glycol Deicing Fluid

There are three main kinds of glycol deicing fluids. These are ethylene glycol monoethyl ether (EGME), diethlylene glycol monoethyl ether (DiEGME), and propylene glycol (PEG). Ethylene glycol is the most popular form of deicing fluid on the market. These are the same compounds used in conventional radiator anti-freeze for automobiles. ADF (Aircraft Deicing Fluid) is supplied in concentrated form and contains approximately 88% by weight glycol.

The fluid has a true freezing point of approximately -65°C. ADF Concentrate must be mixed with the proper amount of water to create a solution for the desired freezing point. Measuring the liquid's refraction can effectively monitor the freezing point of the solution. The magnitude of the refraction is related to the concentration of ethylene glycol contained in the solution. ADF will contain a number of chemical additives including surfactants for surface wetting and biocides. One other component of aircraft deicing fluid is the corrosion inhibitor methylbenzotriazole, (MeBT), which is toxic to fish, algae, and bacteria, and under certain conditions is recalcitrant.

Airplane Deicing

In less sophisticated airports creative means of getting snow and ice off airplanes are used. Some use brooms, squeegees, and rope on the fuselage. The reason for de-icing planes is that frost and snow can affect flight control gear. Also, the lift a plane needs to get off the runway can be affected as even small amounts of roughness caused by ice, snow, or frost can disrupt airflow over the wing surfaces reducing the amount of lift.

Larger airports in areas subject to freezing temperatures use an anti-freeze material that is sprayed onto the plane just prior to take-off. The fluid contains wetting agents that facilitate the uniform wetting and spreading of aqueous dilutions of the fluid on the aircraft surfaces when used in accordance with appropriate application procedures. Thorough coverage of aircraft surfaces by the deicing fluid is necessary to eliminate all frozen accumulations and prevent the freezing of residual fluid on aircraft surfaces. An orange dye is added to the fluid to act as a visual aid, assisting the application and detection of the fluid on aircraft surfaces. Although some airports utilize collection and treatment systems, the majority of ADF used is released into the environment.

Glycol Regulation

As a result of governmental regulation and the inadequacies of existing conventional treatment methods, aircraft deicing fluid wastewater has become both an economic and environmental liability for airports throughout the US and Canada. About 200 to 600 million gallons of spent aircraft deicing fluid containing 1 to 35 vol% glycol are generated per year at over 1,500 airports throughout the U.S.

and Canada today. The EPA has classified this material as a regulated industrial process wastewater under the NPDES 40 CFR Part 122. As a result, disposal of spent deicing fluid has become both an environmental and economic liability and very few airports today have successfully fulfilled the requirements set forth by the EPA. One of the most important environmental issues facing many airports is the runoff and consequential contamination of waterways from glycol pollution. In March of 1992, US Air flight 407 crashed on takeoff at New York's Laguardia Airport during a winter storm due to inadequate deicing.

In the aftermath, the Federal Aviation Administration (FAA) imposed more stringent requirements on deicing activities in order to increase the margin of safety for aircraft operating during winter conditions. These revised FAA protocols (14 CFR part 121) increased the quantities of deicer used by airports. Consequently, this increase has led to greater levels of deicer in the waterways.

Glycol is sprayed on aircraft to keep them from icing up before takeoff and early entry into the atmosphere. Without proper containment, glycol flows into drain systems and into local waterways. This is where the damage is done. Even with elaborate containment systems, wind can blow the hot mist out of bounds where it can escape. Glycol breaks down very quickly and doesn't present a threat to water treatment for humans. Where glycol can be damaging is during the degradation process where it consumes large quantities of oxygen. This robs local fish arid plant life of essential nutrients. No other proven alternative for glycol based deicing fluid is available. Regulation of airport stormwater discharges containing deicing fluids has been, and currently is, a focus of several state regulatory actions (EPA-bulletin-March 99). With the increase of federal safety regulations regarding glycol, airports are forced to spend millions of dollars to trap, treat and release glycol-free fluids into the waters.

Current remedial technology in this area is bulky, expensive and barbaric at best. No acceptable forms of natural or chemically produced compounds have been developed to lessen the effects of glycol before it hits the waterways. A great deal of study is being done to find a "Best Practices" technology for deicing wastewater treatment.

Problems associated with conventional deicing fluid technology treatments

Aerobic Digester -

The glycol cannot be recovered. The typical Aerobic Digester treatment system includes the construction of a flow routing structure (to segregate dilute and concentrated deicing flows), three 2 million gallon aerobic treatment lagoons, and two 62,000 gallon steel storage tanks. Diluted deicing fluid flows are treated in the lagoons to meet permit limits prior to discharge to the POTW or local creeks.

Deicing Waste Storage Lagoons

Distillation -

This can be an effective means of recycling the glycol. However, the condensate cannot be directly discharged to the POTW and must be further treated. The dilute and contaminated washdown water requires pre-treatment ahead of distillation to remove emulsified oils, suspended solids, and other contaminants. Distillation columns are very large and expensive.

Distillation Column for Glycol Deicing Fluid Recovery

Membrane Filtration

To produce a reusable glycol product, it is necessary to reduce the water content as well as remove the turbidity, color, odor, and various other contaminants from spent aircraft deicing fluid. Water can be removed via conventional evaporation technology, but by comparison, membrane filtration has many advantages. An Ultrafiltration membrane can be used to remove suspended solids, turbidity, emulsified oil, color, and odor of spent aircraft deicing fluid. The fluid is filtered removing contaminants at high temperature (75° C) using an Ultrafiltration membrane as stage one.

Next, the deicing fluid (Ultrafiltration Filtrate) can be dewatered using a Reverse Osmosis Membrane as stage two. Since the UF membrane will do a very effective job of removing contaminants, reverse osmosis stage two dewatering can be used, or the UF permeate can be sent to conventional distillation technology to produce the final product concentration.

Economic projections and bench scale tests showed that membrane technology could be integrated to deliver a viable process for the production of high quality ethylene or propylene glycol.

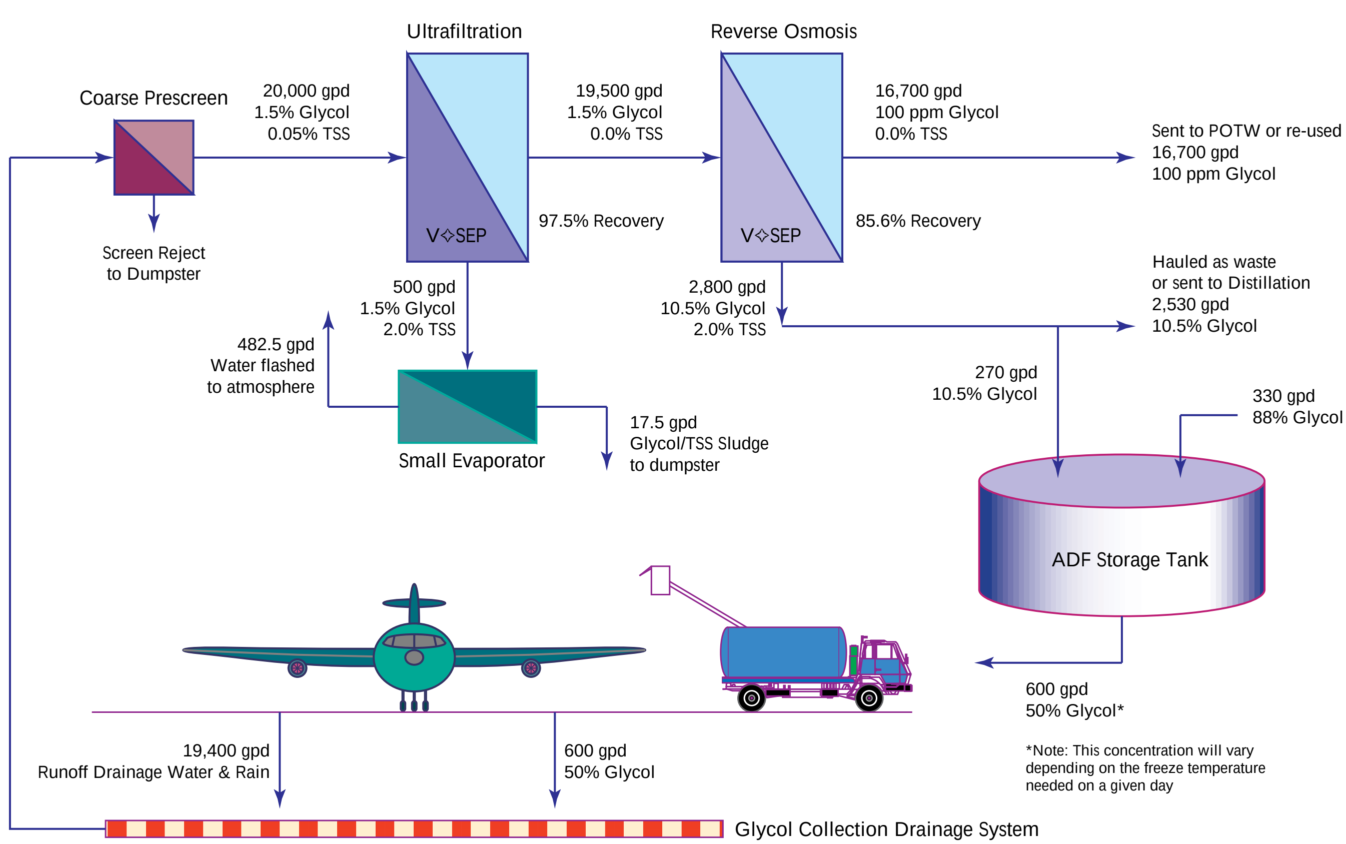
Commercialization Status:

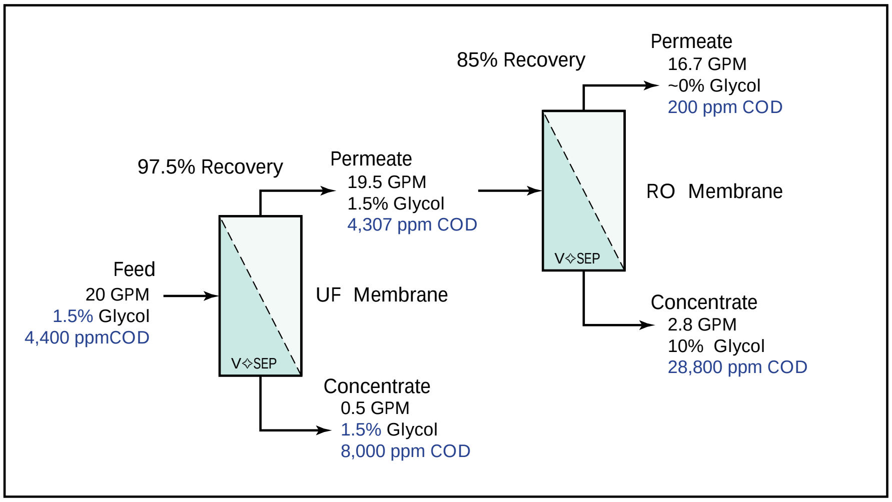
Treatment of spent deicing fluid using polymeric membranes has been commercialized to a limited degree and full-scale systems have been installed and integrated into the existing deicing fluid recovery processes in major US airports. New Logic has participated in pilot testing programs using its vibrational membrane using reverse osmosis to concentrate the dilute (i.e., 1 to 3%) deicing fluid to ~10%. Economic comparisons to conventional methods have shown dramatic operating cost savings and shown V✧SEP to be an effective treatment solution. In addition, V✧SEP represents a cutting edge environmentally freindly solution.

V✧SEP Process

Many scenarios are possible using membrane filtration. This case study looks at the use of ultrafiltration as stage one followed by reverse osmosis filtration as stage two. The spent deicing fluid which has collected rainwater and other drainage waters is now diluted from it original use. This feed water is pumped out of the storage lagoon where it was collected and then is prescreened ahead of filtration using a 100-mesh wire cloth screen to remove sand and large particles. From there it is processed in the first stage where an ultrafiltration membrane clarifies the liquid rejecting suspended solids, emulsified oil, large organics, and other contaminants larger than 20,000

V✧SEP Deicing Treatment Process - Material Balance





Two-Stage V✧SEP Block Diagram for Glycol Recovery

MWCO. The reject from this is sent to a small drum dryer or evaporator for dewatering. This 1/2 gpm waste stream is dewatered leaving a glycol sludge that can be landfilled. The filtrate from stage one now has most of the contaminants removed and is sent to stage two, where an RO membrane is used to dewater the glycol and concentrate the deicing base material up to 10% glycol.

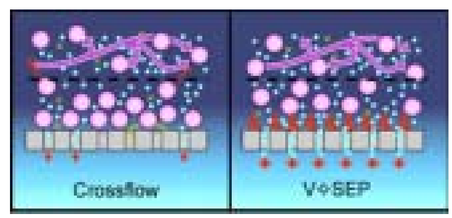
With a molecular weight of less than 100, the glycol can lead to osmotic pressure limitations for filtration. As a result of this high pressure must be used and 10% glycol would be the practical limit for concentration. The RO permeate is low in BOD and can be sewered or reused in the operations. This is where most of the cost savings are realized as the bulk of the volume is water and treating the wastewater can significantly volume reduce the waste leaving very clean water for disposal. The concentrate from stage two has about 10% glycol and can be used to dilute the ADF that is mixed for deicing. The amount of dilution will depend on the calculated freeze temperature.

If 50% glycol is required, V✧SEP can recycle almost half of the needed volume of deicing fluid. This would reduce the purchase cost for glycol based feed stock for deicing. The remaining volume of treated 10% glycol and water can be sent to distillation for glycol recovery or it can be hauled as waste. Even though hauled as a waste, it may have economic value to others operating distillation recovery of glycol.

V✧SEP Technology Overview:

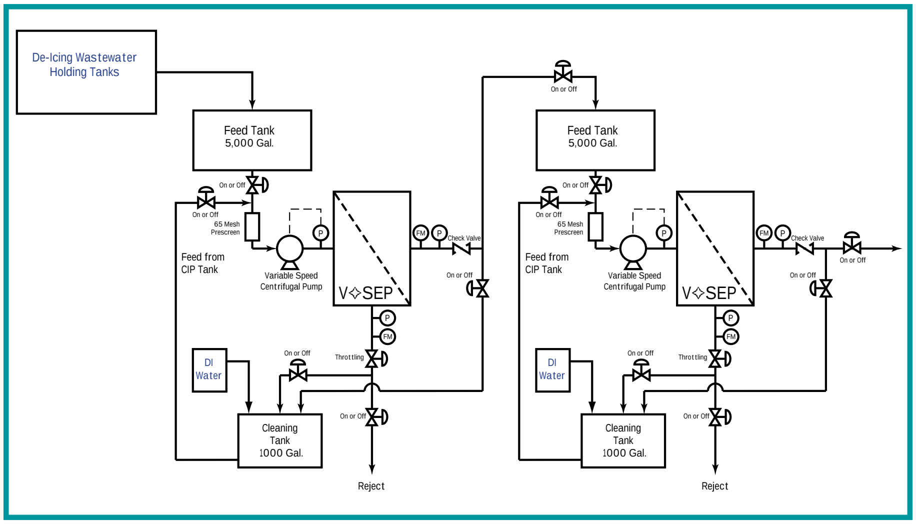
NEW LOGIC developed V✧SEP to meet the needs of the industrial membrane market. Rather than simply preventing fouling with high velocity feed, V✧SEP reduced fouling by adding shear to the membrane surface through torsional vibration. This vibration produces shear waves that propagate sinusoidally from 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. Please see the diagram below for a visual comparison between V✧SEP and traditional crossflow filtration.

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 polytetrafluoroetyhlene (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 1/2" to 1" peak-to-peak displacement. The frequency at which the system vibrates



Two-Stage V✧SEP Process and Instrumentation Drawing

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.

Economics

Minneapolis-St. Paul Metropolitan Airport (MSP) as of March 25,1999, spends approximately $2.3 million per year to trap, treat and transport Glycol to treatment plants.

This existing treatment system prepares the waste for disposal and treatment offsite. It does not fully detoxify the fluid before transport. A complete treatment facility would cost approximately $50 million. This cost is for a method of safely disposing of the spent deicing fluid.

A much more sensible plan would be to recycle the water and glycol rather than disposing of it. New Logic's membrane treatment system can provide just such a solution and, most importantly, at a cost much lower than that of a wastewater treatment plant for disposal.

Glycol recovery system improvements are genreally tax deductible initially. Implementation of recovery systems could save large amounts of money if glycol is recycled rather than just trapped and treated for disposal. There are also political and intangible economic benefits that would result. Less money is spent in remediation of waterways and other environmental releases (lawyers).

Each airport, along with individual airlines, is responsible for research and development on deicing fluid and possible remediation techniques if it enters the waterways. EPA has given airports and airlines the option to do research on their own, with conglomerate groups, or by paying fees to fund the government's research and development.

The table below shows the relative operating costs for V✧SEP when compared to the conventional method of collection and hauling for offsite treatment. By reducing the amount of waste 88%, the V✧SEP system can pay for itself in about 8 months of use as an insitu treatment system.

Deicing Treatment Operating Costs

Description	Description	
Existing Deicing Collection and Disposal Method		
3,000,000 Gallons per year of hauled waste	@ 50 ¢/gal	$ 1,500,000/yr
V✧SEP Membrane Treatment Method*		
V✧SEP System Power Consumption per year	$ 7,180	
V✧SEP Cleaning & Maintenance per year	$ 8,640	
Filter Pack Replacement Cost	$ 65,932	
380,000 Gallons per year of hauled waste @ 50¢	$ 190,000	
Total Annual Cost for the V✧SEP Method		$ 271,752/yr
Total Annual Operating Cost Saving		$ 1,228,248/yr
V✧SEP Payback Period Calculations		
V✧SEP System Purchase Price	$ 545,436	
Building & Accessory costs (for total installed cost)	$ 270,000	
Total Installed Cost for the V✧SEP Method		$ 815,436
Calculated Capital Cost Payback Period		8 Months

*based on operating 6 months out of the year with a 2 V✧SEP system
0.05 $/kW electricity cost

NEW LOGIC RESEARCH

Application Note

Installed V✧SEP Applications

Phosphate Fertilizer
Oily Water Treatment
Coolant Recovery
Used Crankcase Oil Recylcing
Pulp & Paper Effluent
Mineral Processing
Paper Coating Recovery
Copper Milling Lubricant Recovery
Electrolite Bath Clarification
Closed Circuit Water Recycling

For more information, contact:

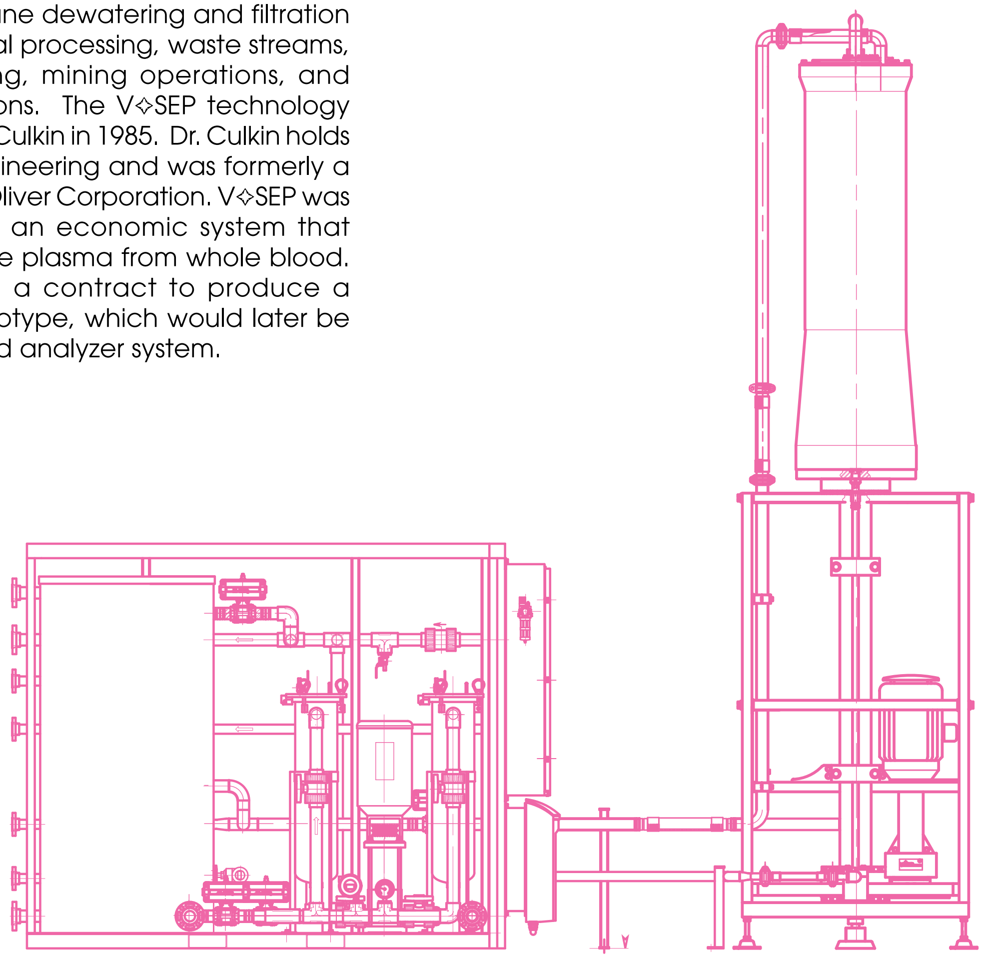
New Logic Research
1295 67th Street
Emeryville, CA 94608 USA
510-655-7305
510-655-7307 fax

info@vsep.com
www.vsep.com

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.

CE



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