NEW LOGIC INTERNATIONAL, INC.

Application Note

High Solid Inorganic Chemicals Processing and Product Recovery

EXECUTIVE SUMMARY

A manufacturer of membrane filtration and solids separation equipment, New Logic International Inc., (New Logic) of Emeryville, CA has now several new and existing projects with major high solid inorganic chemical producers for the use of its technology. New Logic's Vibratory Shear Enhanced Process (VSEP) is being used for the dewatering of high solid inorganic chemical streams and recovery of these materials from the effluent streams. Some of the higher value applications include the manufacturing of titanium dioxide (TiO_2), calcium carbonate ($CaCO_3$), and Kaolin clays. The VSEP is able to dewater these inorganics up to 72 percent solids in a single pass. Other alternatives (such as evaporators and centrifuges) are very expensive to operate due to the high energy consumption as well as the expensive capital equipment.

The advantages of using VSEP for inorganic chemical production/recovery are as follows:

- Product is produced with low energy consumption (reduced load on dryer)
- No chemical treatment is required
- Permeate produced is sewerable and needs no further chemical treatment
- Membrane is easily cleaned using hot water
- VSEP reduces the loading on other process equipment
- VSEP requires a small footprint
- VSEP provides continuous operation
- VSEP is now a commercially proven technology

As a case in point for economic evaluation of using VSEP for treatment of high solid inorganic chemical streams, the economics for dewatering titanium dioxide is presented. For a 3 tons per hour TiO_2 product recovery facility, a simple payback period of less than one year is estimated. The primary savings result from the reduced load on the dryer energy requirements. If the cost savings from product recovery is also included, the recovery of this product alone can pay for the cost of VSEP treatment system in less than a few days.

New Logic's VSEP technology is being incorporated into various applications for water pre-treatment, recycling and wastewater treatment. It can filter streams containing a variety of contaminants without the fouling problems exhibited by some conventional membrane systems. The process not only filters suspended solids but also reduces BOD, COD and color bodies. The result is a clear, reusable water stream and a concentrated sludge. The key factor to VSEP's performance and resistance to membrane fouling is its ability to generate shear forces at 150,000 inverse seconds which is ten times greater than the shear in conventional cross-flow systems.

BACKGROUND

There are many manufacturing facilities for production of high solid inorganic chemicals (including minerals and clays) in the United States and elsewhere. The treatment of high solid inorganic chemical streams and recovery of these materials from the effluent streams are important technical and economic challenges currently facing these industries. Some of the higher value applications include the manufacturing of titanium dioxide (TiO_2), calcium carbonate ($CaCO_3$) and Kaolin clays. The worldwide production of these products alone is about 40 million tons per year. During the refining and processing of these inorganic chemicals, the solids are suspended in an aqueous slurry. Some product is shipped as a 60 to 70% thick slurry. Other times it must be dried and is shipped as a dry powder containing very little water. In any event, the aqueous slurry as produced typically has a solids concentration of 5 to 40% by weight and must be dewatered to about 60 to 70%.

Titanium Dioxide (TiO_2) is a very important pigment in the production of quality coated papers as well as production of paints and pigments. TiO_2 pigments are finely divided, chemically inert white powders, which possess a higher refractive index than any other commercially available pigment. Its unique properties provide proper opacity and brightness development unequaled by other coating pigments. Two TiO_2 crystal forms, anatase and rutile, differ in properties that affect their optical performance. Incorporating TiO_2 into the paper coating, paints and pigments significantly enhances sheet or surface opacity and brightness.

Anatase TiO_2 is produced by the sulfate process and essentially all commercial rutile TiO_2 is produced by the chloride process. The excellent refractive abilities of TiO_2 results in a relatively small amount required as an additive. All paints have TiO_2 in them to some degree. Thus massive amounts of this material are required worldwide, with production estimated at 7.3 million tons per year. There are two main raw materials which are harvested to process TiO_2. These are Ilmenite Ore and Rutile Beach Sand deposits. The Eastern Seaboard of the United States has one of the largest Ilmenite deposits in the world. It is also found in Northern Europe and Australia. The largest Rutile Beach Sand deposits are found in South Africa, India, Madagascar, Sierra Leone (Western Africa), Tasmania, Florida, and California.

Calcium Carbonate ($CaCO_3$) is one of the most versatile mineral fillers and is consumed in a wide range of products including paper, paint, plastics, rubber, and textiles. High purity calcium carbonates are used in dentifrices, cosmetics, foods and pharmaceuticals. The worldwide production of this product is estimated at 15.4 million tons per year.

Calcium carbonate makes a suitable paper coating that has good brightness and is cheaper than TiO_2. Calcium carbonate is produced in two different ways, precipitated and ground. They differ greatly in characteristics and usefulness. Precipitated has much better purity and therefore better brightness. The morphology can also be closely controlled during processing to control the size, shape, and surface area to fit a particular need. Ground calcium carbonate has other impurities such as Kaolinite, iron oxide, magnesium, and dolomite. These impurities lead to a less controlled product with lower brightness.

Since calcium carbonate is inexpensive, it can be used as a filler/extender when combined with other more expensive materials. Ground calcium carbonate (GCC) is used where quality and brightness is not as important. Precipitated calcium carbonate (PCC) is 99% pure and is used mainly as a paper coating substitute for TiO_2. The use of PCC as paper coating is increasing as paper makers are going away from acidic papers and are producing alkaline paper products. In addition to paper products, calcium carbonate is used for soap, tires, plastic, rubber, toothpaste, and several other products. Some of the purest deposits are found in the Southeastern United States. The production of ground calcium carbonate is estimated at 11.2 million tons per year and the production of precipitated calcium carbonate is estimated at 4.2 million tons per year.

Kaolin Clays: There are a number of mineral species called clay minerals, which contain mainly mixtures of Kaolinite ($Al_2O_3.2SiO_2.2H_2O$). Clay is chemically inert and very inexpensive to mine and to process. As a result, it is used widely as a filler material or extender in ceramics as well as in paints, coatings, paper, plastic and other products. The worldwide production of this product is estimated at 16.8 million tons per year.

Kaolin Clay generally has a finer quality and smaller particles. Thus, it is used for fine ceramics and for paper coating where quality is important. Bentonite clay is another important clay product that is also used for adhesives, mortar, and fillers and can also be used as a capping layer for waste disposal sites.

OBJECTIVE

The treatment of high solid inorganic chemicals and recovery of these chemicals from the effluent streams are important technical and economic challenges currently facing the various high solids industries. The filtration of process and effluent streams allows an inorganic chemical processing plant to recover product, meet discharge requirements and/or provide a clean source of reusable water. The economical dewatering of the process or effluent streams and added product recovery are in most cases highly desirable.

SOLUTION

Technological advances in membrane filtration systems have created an opportunity for inorganic chemicals processing plants to implement a cost effective way of dewatering inorganic chemicals (or minerals), at the final product stage or before final treatment with a dryer or a filter press. The "Vibratory Shear Enhanced Processing" or VSEP™, developed by New Logic International makes it possible to filter process or effluent streams without the fouling or plugging problems exhibited by conventional membrane systems. The VSEP membrane system will effectively dewater the inorganic chemical streams to the required solid levels, up to 72% solids.

Several technologies are currently being used for solids dewatering from dilute solids slurry streams. Table 1 presents a summary of the benefits of VSEP when comparing with selected competitive technologies such as evaporators, dissolved air floatation (DAF) units, clarifier systems, rotary vacuum concentrators, centrifuges, cross flow filtration/ spiral membranes, and filter presses. VSEP offers significant advantages over all of these technologies, as presented in Table 1.

The VSEP treatment system uses microfiltration or ultrafiltration membrane modules to treat the inorganic chemicals process or effluent streams in order to generate a concentrate stream with the desired solids concentration and a permeate stream that meets the water discharge or reuse criteria. VSEP preconcentrates solids (for example TiO_2, calcium carbonate, Kaolin clay) prior to the final evaporation or drying step to manufacture a concentrated slurry product. Thus VSEP can integrate with existing conventional technologies or replace them, depending on the process requirements or the economics of a given product recovery system.

In addition, the clear permeate can then be discharged or recycled to the process. The VSEP membrane system will also reduce BOD, COD, TDS, and TSS from effluent streams. In summary, the VSEP treatment system can be used to treat inorganic chemicals plant effluent in order to recover the solids. It can also be used to supplement the evaporator/dryer (or other dewatering technologies) at the facility, thus increasing the plant energy efficiency by reducing the load to the dryer.

In the inorganic chemicals manufacturing industry, VSEP membrane systems can now be utilized where traditional cross-flow membrane technologies faced substantial membrane fouling problems in the past. The VSEP is an attractive alternative to conventional filtration methods due to its vibrational, shear-enhanced design.

Table 1
Benefits of VSEP when Comparing with Competitive Technologies

Technology	Benefits of VSEP

Evaporators	• **VSEP can be expanded in small increments for capacity increases**
	• **Capital cost for VSEP is much lower than that for the evaporation treatment system.**
	• **Evaporators consume massive amounts of energy, resulting in very high operating costs.**
	• There are usually large amount of scaling and fouling in evaporators.
	• At low dissolved solids, evaporators tend to exhibit poor thermodynamics and are physically large.
	• VSEP can handle wide variations in feed concentrations.
	• VSEP offers smaller footprint, thus much lower facility cost.
	• Highly likely that evaporation processes needs additional pretreatment over VSEP
	• **Benefits in Conjunction with Evaporator Systems**
	    • VSEP can pretreat the feed to the evaporator systems to enhance the performance of the evaporators. The concentrate can go to the evaporator.
	    • VSEP can treat the effluent from the evaporator systems to meet carry over dissolved solids

Rotary Vacuum Concentrators	• **The main advantage of VSEP over rotary vacuum drum filter systems is that the latter are very expensive.** The capital required for a vacuum drum filtration system requires auxiliary equipment such as vacuum system, pipes, a heavy foundation, controls, flocculating chemicals and precoating materials such as diatomaceous earth. • **Precoat is required for treatment with rotary vacuum filters and this adds to the waste volume generated and mixes with product. Operating costs are also high.** • **Rotary vacuum filters usually have a three to five micron particle size limit and typically perform the best in the 10 to 50 micron range. However, VSEP can handle wide variations in feed concentrations, from 800 microns down to 1/1000th of a micron.** • Rotary vacuum filters consume large amounts of energy • For most applications, rotary vacuum filters need significant additional treatment steps over VSEP • Most of the vacuum filters operate in a batch mode, where as VSEP operates in a continuous mode, resulting in much higher throughput • The greatest disadvantage of a rotary vacuum filter system is its size, with some systems as large as a building. • VSEP offers smaller foot print, thus much lower facility cost • Rotary vacuum filters **can only produce a dry filter cake and must be re-slurried when a slurry product is desired.** The added precoat may preclude the use of rotary vacuum filters.
Centrifuges	• **Centrifuge generates a cloudy overflow that often may not meet the criteria for disposal.** • **Centrifuge's major draw back is that it is a maintenance headache and requires experienced technicians to maintain** • Several spare parts must be stocked in order to be able to perform maintenance quickly and effectively • Centrifuges are very large and have a lot of heavy moving parts • Centrifuges have high energy consumption • If centrifuges work, they are a bargain but they don't always work well. • VSEP does not require difference in specific gravity to accomplish separation • VSEP can get to higher concentrations • VSEP can handle wide variations in feed concentrations and can handle molecular separation. Centrifuge is primarily used for particle separations greater than 10 microns • VSEP generates crystal clear overflow (permeate) • VSEP is low maintenance and minimal operational attention is needed and low skill labor can work on VSEP equipment • VSEP offers smaller foot print, thus much lower facility cost
Dissolved Air Floatation (Chemical Addition/ DAF	• **The main advantage of VSEP over a DAF treatment system is that the chemical addition costs are usually very high for DAF.** • VSEP can handle wide variations in feed concentrations. • VSEP generates a permeate quality with 0 ppm suspended solids versus about 500 ppm from a DAF treatment process

Table 1
Benefits of VSEP when Comparing with Competitive Technologies

Technology	Benefits of VSEP
Dissolved Air Floatation (Chemical Addition/ DAF)	• VSEP is a one step process where as the DAF treatment process generally requires pre and post treatment • VSEP can obtain higher quality permeate, typically less than 100 to 200 ppm of BOD • VSEP offers smaller foot print, thus much lower facility cost • The chemical consumption for DAF units is usually even higher than projected and significant overdose is required for proper control of the DAF effluent.
Clarifier Systems	• **The main advantage of VSEP over a clarifier system is that the settling that a clarifier requires is a great deal of time which leads to clarifiers with a great hold-up volume and thus large space required and cloudy overflow.** • VSEP can handle wide variations in feed concentrations • VSEP generates a permeate quality with 0 ppm suspended solids versus about 500 ppm from a clarifier treatment process • VSEP is a one step process where as the clarifier treatment process generally requires pre and post treatment • VSEP can obtain higher quality permeate, typically 100 to 200 ppm of BOD • VSEP offers smaller foot print, thus much lower building/facility costs • The chemical consumption for clarifiers is usually high and significant overdose is required for proper control of the clarifier effluent.

Filter Presses	• **Filter presses can only produce a dry filter cake and must be re-slurried when a slurry product is desired.**
	• **Filter presses consume large amounts of energy.**
	• **Filter presses usually have a three to five micron particle size limit and typically perform the best in the 10 to 50 micron range. However, VSEP can handle wide variations in feed concentrations, from 800 microns down to 1/1000th of a micron.**
	• For most applications, filter presses need significant additional pretreatment over VSEP
	• Most of the filter presses operate in a batch mode, where as VSEP operates in a continuous mode, resulting in much higher throughput and eliminating tankage.
	• The greatest disadvantage of a filter press is its size, with some presses as large as a building. VSEP offers smaller foot print, thus much lower facility cost
	• **Benefits in Conjunction with Filter Press**
	    • VSEP can pretreat (preconcentrate) the feed to the filter press to reduce the capacity required for the filer press
	    • VSEP can treat the effluent from the filter press to meet COD/BOD demands and remove small particles that pass through the press

Cross-flow Filtration/ Spirals	• **Product concentration is poor with cross flow systems, with cross flow at e.g. 5% to 30% solids versus 70% typical for VSEP** • **Cross flow filtration normally requires pretreatment** • **VSEP offers higher end point solids** • Frequent membrane replacement for the cross flow system can become expensive • Cross flow membranes will plug up with high solid streams • Hold-up volume of cross flow system is high • Need larger feed/working tank with cross flow filtration • Larger piping is required for cross flow filtration • VSEP offers 2 to 3 times higher flux • VSEP offers one pass operation • VSEP can handle wide variations in feed concentrations • VSEP can obtain higher quality permeate, typically 100 to 200 ppm of BOD • VSEP offers much lower power requirement. • VSEP offers smaller foot print, thus much lower facility cost

PROCESS CONDITIONS

The manufacturing of titanium dioxide (TiO_2), calcium carbonate ($CaCO_3$) and Kaolin clays generally involve treatment of high solid inorganic chemical streams and recovery of these chemicals from the effluent streams. The following presents a discussion of general manufacturing processes for each of these inorganic chemicals (including minerals/ clay) examples, how to integrate VSEP into the treatment process, and schematics of the processes for the concentration steps using the VSEP treatment system.

Titanium Dioxide (TiO_2)

All titanium bearing ores or deposits will have impurities that need to be removed. This is done in a refining process. There are two refining processes: the Sulfate Process and the Chloride Process.

Titanium Dioxide (TiO_2) Production - Sulfate Process: An overall flow chart is presented in Figure 1. In this process, finely ground Ilmenite ore concentrate reacts with sulfuric acid to obtain a reaction mass consisting of soluble iron and titanium sulfate. After the unreacted ore and insolubles are removed by clarification and filtration, the solution is concentrated by evaporation and cooled to crystallize the iron as ferrous sulfate, which is separated and discarded.

The remaining solution is heated to hydrolyze the titanium and precipitate it as amorphous hydrous titanium dioxide. If rutile is the desired product, the solution prior to hydrolysis must be nucleated with rutile crystallites to obtain a hydrolysis product suitable for conversion to rutile crystals. The hydrous titanium dioxide slurry is then filtered to recover and purify the titanium dioxide.

The hydrous titanium dioxide is then calcined in rotary kilns under conditions to crystallize and grow the pigmentary titanium dioxide crystals to the desired 0.25-micron particle size. The particle size distribution achieved by the sulfate process is typically wider than that of the chloride process because of the long calcination cycle. A final drying step allows the production of bagged dry titanium dioxide. The VSEP treatment system can preconcentrate the titanium dioxide before feeding to the evaporator/ dryer or in preparation for delivery as a slurry product. As you can see in the diagram, the addition of VSEP ahead of the dryer to preconcentrate the process effluent reduces the load on the dryer significantly, thus improving the process efficiency.

Titanium Dioxide (TiO_2) Production - Chloride Process: An overall flow chart is presented in Figure 2. In this process, finely ground ilmenite ore concentrate reacts with gaseous chlorine at high temperatures in the presence of carbon to produce anhydrous titanium tetrachloride, iron chlorides, and chlorides of other metals present in the ore. The gaseous products are then cooled to affect the primary separation of titanium tetrachloride from the high boiling iron chlorides. The crude liquid titanium chloride is then fractionally distilled to remove low and close boiling components.

The purified titanium tetrachloride is vaporized and reacted with preheated air or oxygen to form titanium dioxide crystals and chlorine. After the product stream is cooled, the solid titanium dioxide is separated from the gaseous chlorine that is recycled to the chlorination step. This process effluent is typically sent to a dryer or an evaporator in order to concentrate the solids to 60 to 70% by weight. The final drying step allows the production of bagged dry titanium dioxide. The VSEP treatment system can preconcentrate the titanium dioxide before feeding to the evaporator/ dryer or in preparation to delivery as a slurry product.

A typical process schematic for dewatering titanium dioxide using a VSEP system is presented in Figure 3. This diagram depicts an actual commercial process that has been in operation in the United States since 1994. This diagram includes the overall material balance for the titanium dioxide process effluent treatment system and illustrates the performance of the VSEP unit. Process/effluent stream from the titanium dioxide manufacturing process is fed to the feed storage tank and the VSEP units at a rate of 30 gpm. Three industrial scale VSEP units, using ultrafiltration membrane modules, dewater the process/effluent stream.

Figure 1
Overall Flow Chart
Titanium Dioxide Manufacturing - Sulfate Process
Including V✧SEP Dewatering System

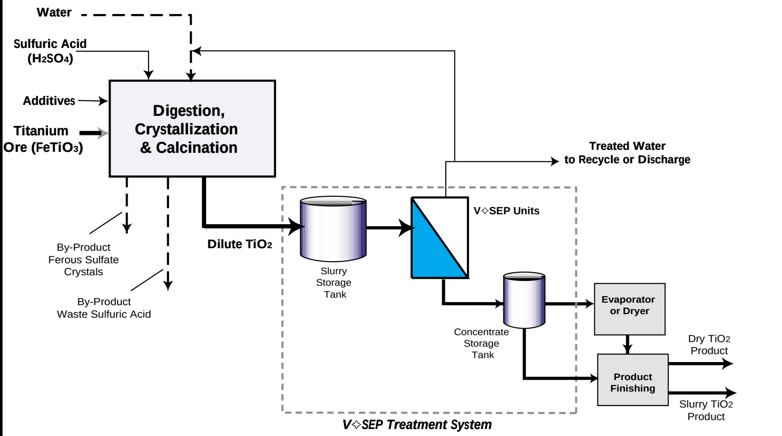


Figure 2
Overall Flow Chart
Titanium Dioxide Manufacturing - Chloride Process
Including V✧SEP Dewatering System

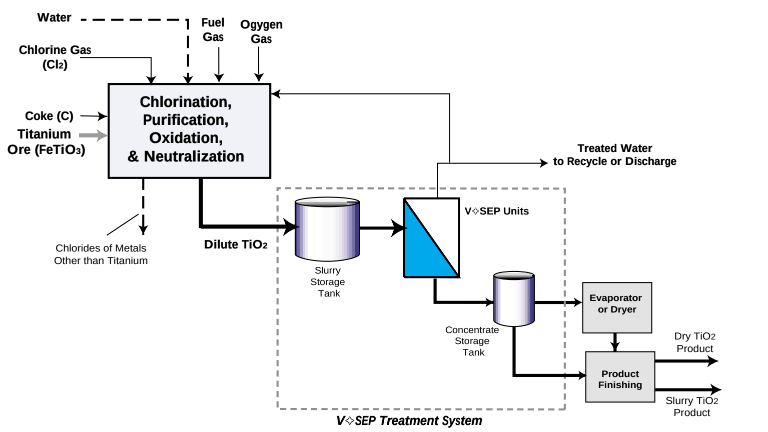
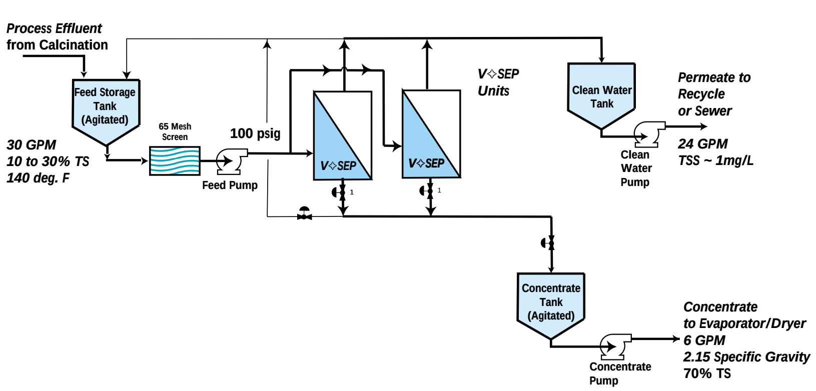


Figure 3
Schematic of Titanium Dioxide Dewatering Using V✧SEP
(Production of 3 Tons/Hr of Titanium Dioxide)



The VSEP produces a concentrated stream at a flow rate of about 6 gpm that is directed to the evaporator/ dryer unit or the product-finishing unit. Concentration of the feed to the VSEP unit ranges from 10 to 30% by weight of total solids (titanium dioxide). The concentrated stream contains approximately 60-70% by weight of total solids. The VSEP treatment system also generates a permeate stream of about 24 gpm which can be recycled to the process or routed to the sewer. The permeate concentration of solids is less than 5 mg/L of TSS, well below the design criteria for process recycle or discharge requirements.

Using an ultrafiltration module in the VSEP system is a commercially viable option for treatment of titanium dioxide process or effluent streams. Nearly 80% of the process or effluent is recovered as treated water suitable for reuse or discharge, while less than 20% is fed to the dryer as concentrate, thereby reducing the load to the dryer by a great margin.

Membrane selection is based on material compatibility, flux rates (capacity) and concentration requirements. In this example, the concentration factor can be over five times while titanium dioxide is concentrated from 10 to 30% to about 70% by weight, which would allow the plant to reduce the load on the dryer system. The permeate quality from the VSEP can be controlled though laboratory selection of membrane materials available to fit the application parameters.

Calcium Carbonate ($CaCO_3$)

The raw calcium carbonate ore will have impurities that need to be removed. This is completed in a refining process. Production of Fine Ground Calcium Carbonate (FGCC) and Precipitated Calcium Carbonate (PCC) do not require much in the way of chemical treatment or the use of liberating agents to purify the substance. The technique used is a series of mechanical segregating operations that remove mica, sand, quartz, iron oxides, and other foreign substances. All through this process the calcium carbonate is suspended with water as a dilute slurry of about 5 to 30% solids content.

Figure 4 presents an overall flow chart for Precipitated Calcium Carbonate manufacturing process. The first step in processing is the transformation of lime (CaO) into “milk of lime” ($Ca(OH)_2$) with excess water. The result of this exothermic reaction is a calcium hydroxide slurry. The carbonation reaction is a process of absorption that is a reversible chemical reaction. Milk of lime will react with carbon dioxide to produce calcium carbonate and water. Precipitated calcium carbonate has fewer impurities than ground calcium carbonate as well as higher brightness and controlled morphology (particle size, shape, and surface area).

Milling, shaker, screens, centrifuges, magnetic classifiers and other mechanical devices are used to remove impurities. The quality of the finished product is highly dependent on small variations in the amount of each of the mineral impurities, which remain. Keeping the calcium carbonate within specifications is an important engineering design issue.

Once the processing is complete, the calcium carbonate slurry must be dewatered to a 70% solids level or higher. Some finished product is shipped as a 70% solids slurry. Other products require a final evaporator/drying step to convert the slurry to a dry powder product.

A final drying step allows the production of bagged dry calcium carbonate. The VSEP treatment system can preconcentrate the calcium carbonate before feeding to the evaporator/dryer or in preparation for delivery as a slurry product. As you can see in the diagram, the addition of VSEP to preconcentrate the process effluent reduces the load on the dryer significantly, thus improving the process efficiency. If a concentrated slurry is the only final product desired, the need for the dryer can be entirely eliminated.

A typical process schematic for treatment of a calcium carbonate process stream using a VSEP system is presented in Figure 5. This diagram includes the overall material balance for the calcium carbonate process effluent treatment system and illustrates the performance of the VSEP units. Process/effluent stream from the calcium carbonate manufacturing process is fed to the feed storage tank and the VSEP units. Industrial scale VSEP units using microfiltration membrane modules treat the process/effluent stream.

Figure 4
Overall Flow Chart
Precipitated Calcium Carbonate Manufacturing
Including V✧SEP Dewatering System

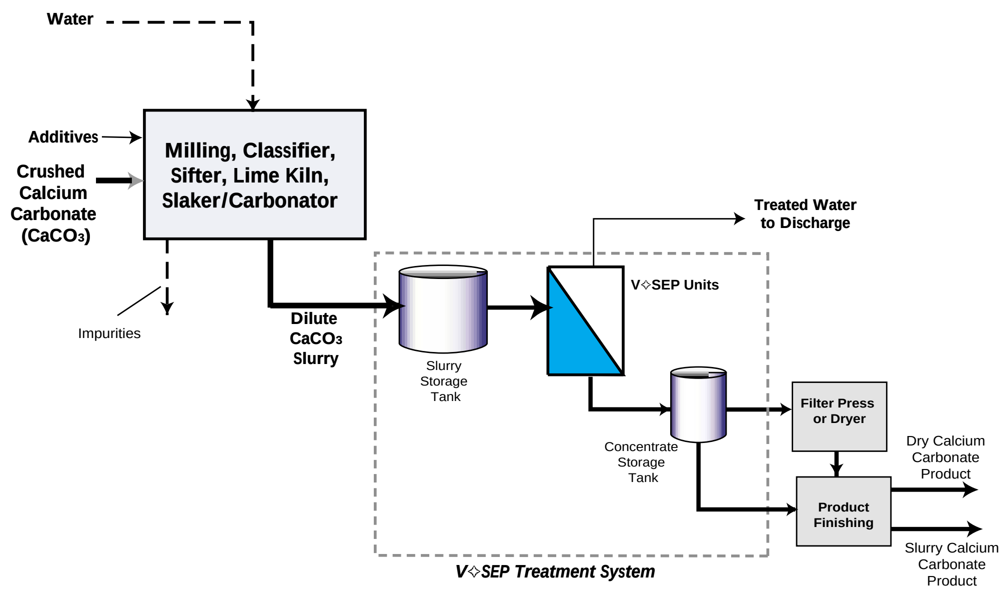
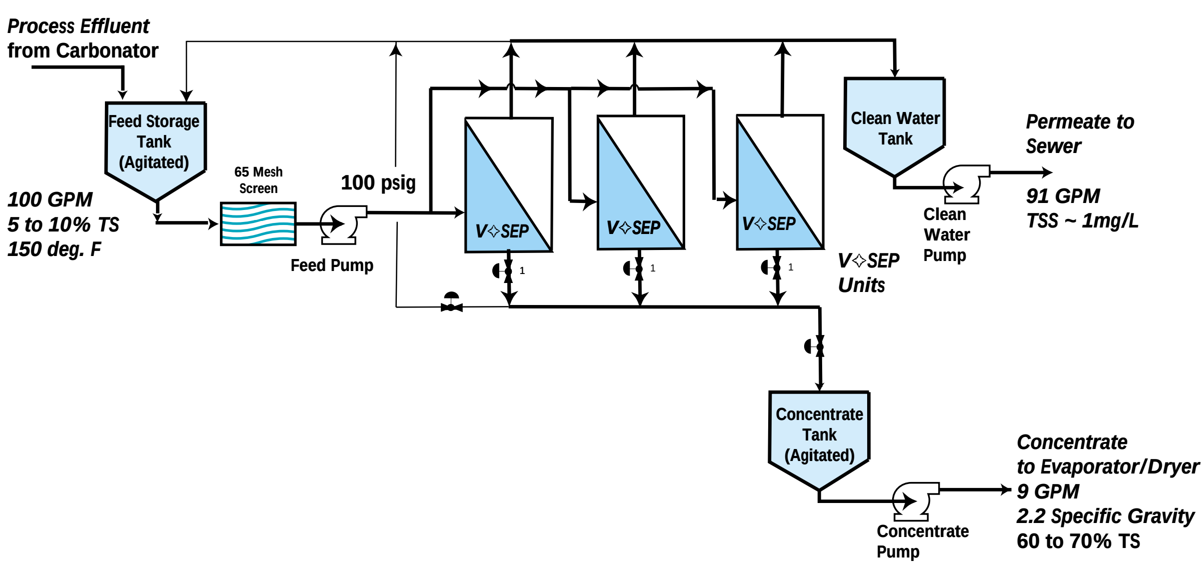


Figure 5
Schematic of Calcium Carbonate Dewatering Using V✧SEP
(Production of 4 Tons/Hr of Calcium Carbonate)



The VSEP produces a concentrated stream that is directed to the evaporator/dryer unit or shipped as a slurry product. The concentrated stream contains approximately 60-70% by weight of total solids. VSEP also generates a permeate stream from the VSEP units that can be recycled or is routed to the sewer. The permeate concentration of solids is less than 5 mg/L of TSS, well below the design criteria for discharge requirements.

Using a microfiltration or an ultrafiltration module in the VSEP system is a commercially viable option for treatment of calcium carbonate process/effluent streams. Nearly 90% of the process/effluent is recovered as treated water suitable for discharge, while less than 10 to 20% is fed to the dryer as concentrate (thereby reducing the load to the dryer by a great margin) or shipped as a slurry product without any use of a dryer.

Membrane selection is based on material compatibility, flux rates (capacity) and concentration requirements. In this example, the concentration factor can be over five times while calcium carbonate is concentrated from 5 to 30% to about 70% by weight which would allow the plant to reduce the load on the dryer system. The permeate quality from the VSEP can be controlled though laboratory selection of membrane materials available to fit the application parameters.

Kaolin Clays

Inexpensive raw materials are typically used in manufacturing the traditional, high volume ceramics. Figure 6 presents an overall flowchart for Kaolin clay manufacturing process including VSEP dewatering system. In its raw form, all clay deposits will have impurities that need to be removed. This is done in a refining process. Unlike other chemical processing operations, clay does not require much in the way of chemical treatment or the use of liberating agents to purify the substance. The technique used is a series of mechanical segregating operations that remove mica, sand, and other foreign substances. All through this process the clay is suspended with water as a slurry of about 10 to 40% solids content.

Impurities are removed using degritting, shaker, screens, centrifuges, electromagnetic separators, and other mechanical devices. Upon removal of all foreign objects, different clays are blended carefully to achieve proper mixing of individual component ingredients. Keeping the clay within specifications is an elaborate process. Once the processing and blending are complete, the clay slurry must be dewatered to 70% solids or higher. Some finished product is shipped as a 70% slurry. Other products require a final evaporation/drying step to produce a dry powder product.

A final drying step allows the production of bagged dry Kaolin clay. The VSEP treatment system can preconcentrate the Kaolin clay before feeding to the evaporator/dryer or in preparation for delivery as a slurry product. As you can see in the diagram, the addition of VSEP ahead of the dryer to preconcentrate the process effluent reduces the load on the dryer significantly, thus improving the process efficiency.

A typical process schematic for treatment of a Kaolin clay process stream using a VSEP system is presented in Figure 7. This diagram depicts an actual commercial process that is planned to be operational in the United States in early 2,000. This diagram includes the overall material balance for the Kaolin clay process effluent treatment system and illustrates the performance of the VSEP unit, including a heat exchange process.

The overall process is designed to manufacture six dry tons per hour of Kaolin clay with a concentration of 63 to 65 percent total solids. Process/effluent stream from the Kaolin clay manufacturing process is fed to the feed storage tank and the VSEP units at a rate of 40 gpm and a concentration of 42% total solids. This stream will be pumped as a split stream through two parallel heat exchangers denoted as Heat Exchangers No. 1 and No. 2. The dilute Kaolin clay slurry streams will be recombined and passed through a final heat exchanger denoted as Heat Exchanger No. 3.

The preheated dilute Kaolin slurry will then be dewatered using two VSEP industrial scale units, thereby obtaining a product stream with a concentration of 63% total solids. The permeate stream will be passed through Heat Exchanger No. 2 to recover thermal energy prior to subsequent processing. A source of supplemental heat will be required to maintain the desired temperatures of the feed to the VSEP units. An

Figure 6
Overall Flow Chart
Kaolin Caly Manufacturing Process
Including V✧SEP Dewatering System

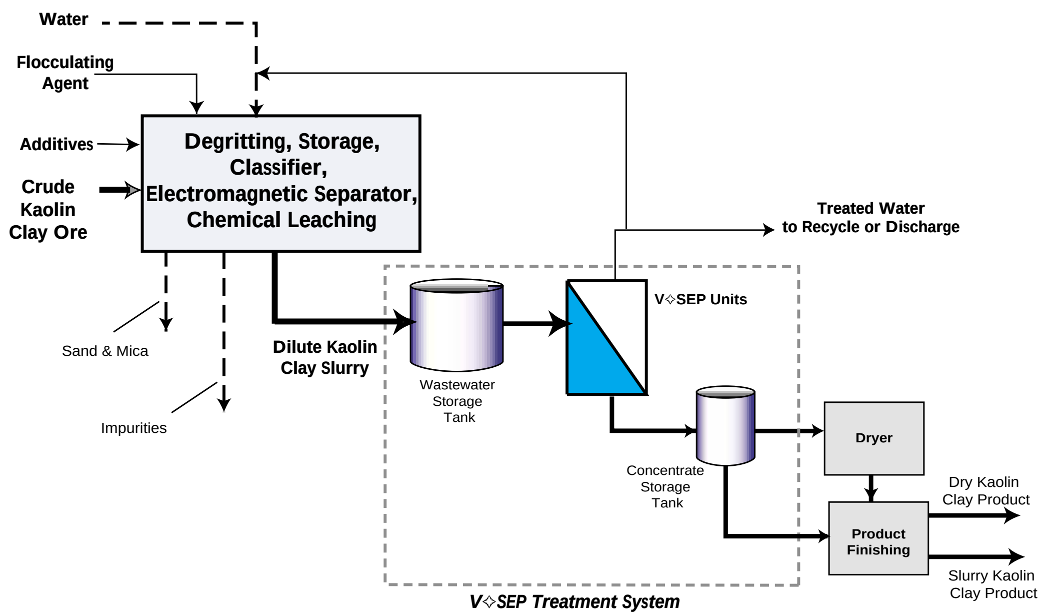
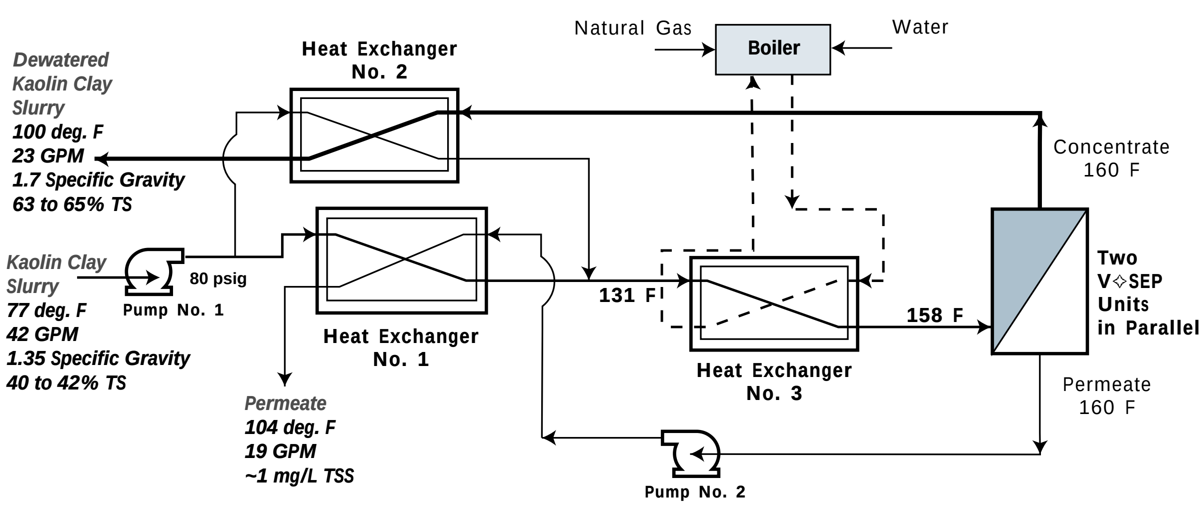


Figure 7
Schematic of Kaolin Clay Dewatering Using V✧SEP and Heat Exchange Process
(Production of 6 Dry Tons of Kaolin Clay)



on-site boiler will provide the additional energy required for the exchanger operation via circulation of heated water through a recirculation loop between the boiler and Heat Exchanger No. 3.

Two industrial scale VSEP units in parallel, using ultrafiltration membrane modules, process the process/effluent stream. The VSEP produces a concentrated stream at a flow rate of about 22 gpm that is directed to the evaporator/dryer unit or shipped as a slurry product. The concentrated stream contains approximately 63-65% by weight of total solids. VSEP also generates a permeate stream of about 18 gpm that can be recycled or is routed to the sewer. The solids level in the permeate is less than 5 mg/L of TSS, well below the design criteria for process recycle or discharge requirements.

PILOT TESTS & PROJECTS

A number of successful pilot tests have been conducted at New Logic for high solid inorganic chemicals processing and product recovery from effluent streams. A number of commercial projects are either in operation or under construction for processing and dewatering of high solid inorganic chemicals streams. Depending on process temperatures, membrane selection and the requirement for concentration of solid streams, the permeate flux rate in the VSEP can range from 10 to over 50 gallons per day per square foot (GFD). The concentration level out of the VSEP unit is controlled by an automatic control valve. This valve is set such that the concentration of the solids is held at the desired level. A multi-stage feed pump or a progressing cavity pump supplies the VSEP unit at a pressure suitable for the membrane used. A variable frequency electronic drive is used to set feed pressure through P.I.D. (Proportional-Integral-Derivative) control loop. This kind of drive acts to control the rotational speed of the pump, thus controlling the flow rate.

ECONOMIC VALUE

As a case in point for economic evaluation of using VSEP for treatment of high solid inorganic chemical streams, the economics for dewatering titanium dioxide is presented here. The economics for dewatering Titanium dioxide have been calculated based on the process flow diagram presented in Figure 3.

For the VSEP treatment system, the operating costs are calculated based on the power costs to operate the filter units (30 HP), filter feed pump (3 HP), filter cleaning cost, and membrane replacement, and the operating labor that would be required. In addition, the water heating/evaporation costs that would be saved due to the amount of water that would no longer require heating/evaporation in the dryer are calculated. Results from the operation also point to substantial additional savings that result from not having to invest in additional spray dryer capacity (savings in capital cost have not been included). The concentration/dewatering function of VSEP results in reducing the load on the spray dryer and thus debottlenecking the plant production of titanium dioxide.

Operation and maintenance (O&M) costs are also presented in Table 2. Savings realized upon installation of VSEP and the pay back period are presented in Table 3.
Cost savings associated with the reduced dryer energy requirements are also
presented. The energy costs are based on rate information from a Northwestern U.S. setting, typically about $0.32/therm, as well as a European setting, ranging up to $0.60 per therm.

New Logic's VSEP system provides a commercially proven alternative approach for inorganic chemicals/ minerals processing and product recovery applications. In a single operation step, VSEP will dewater suspended solids and also reduce BOD, COD, TSS, TDS and color to provide a high quality stream for discharge or reuse in the process. In many applications, the addition of VSEP will eliminate conventional treatment process requirements and technologies without chemical treatment demands. The justification for the use of VSEP treatment system in your process is determined through analysis of the system cost and benefits including:

- Recovery of solids products from the effluent streams.
- Efficient dewatering of the inorganic chemical/mineral slurry streams prior to drying or final shipment.
- Reduction of effluent discharge volume and associated treatment cost.
- Provision of high quality water for reintroduction into the process.
- Offset fresh water demands and pretreatment cost.
- Retain heat in recycled process water, thus reduce energy requirements.
- Simplify effluent treatment with a compact, low energy system.
- Single step process

(a) The VSEP system consists of three industrial scale VSEP units and is able to process 30 gpm of dilute titanium dioxide from the manufacturing process and produce near 6 gpm of a 70% solids slurry and a 24 gpm permeate suitable for recycle or dischar

(b) Labor costs include raw salary as well as company paid benefits.

(c) Assumes a Northwest U.S. setting. For other regions, a rate of $0.4 to $0.6 per therm may have to be used.

Table 3
Savings Realized Upon Installation of VSEP

Feed Rate	Permeate Flow Rate	Concentrate to Dryer	Total Cost Savings per Year @ $0.32/Therm (a)	Total Cost Savings per Year @ $0.60/Therm (a)	Payback Period (b)
(gpm)	(gpm)	(gpm)	($/year)	($/year)	Months
30	24	6	$554,720	$1,119,200	

(a) Assumes operation 24 hours per day for 350 days per year.

Pay back period calculations are based on primarily the cost savings associated with the reduced dryer energy requirements.

Application
Note

SUMMARY

New Logic International has supplied VSEP separation technology successfully into many industrial processes. The high solids inorganic chemical processing industry's effort to dewater process streams and recover products from effluent streams will be enhanced with the utilization of membrane filtration techniques combined with "Vibratory Shear Enhanced Processing". The development towards applications for inorganic chemicals processing, along with the availability of new membrane materials and VSEP 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 VSEP 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.**

REFERENCES

Kroschwitz, J. I., and Howe-Grant, M., Kirk-Othmer Encyclopedia of Chemical Technology, Fourth Edition, John Wiley and Sons, 1996, Vol. 4, pp. 787-801, Vol. 5, pp. 603-621, & Vol. 18, pp. 10-52.

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