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Produced Water Society Seminar 2007

Filtration of Oilfield Produced Water to make Steam Boiler Feed Water

Background

Oil drilling is a major industry that provides different grades of oil and gas for consumption. The oil can be found in formations in the earth from ancient sea or lakes beds. After the reservoir is tapped, the initial oil flow is sufficient due to the amount of pressure. As oil is extracted from the reservoirs, the pressure decreases and the oil becomes more difficult to extract. To maintain the flow of oil, steam can be injected into the wells to force the oil out to increase product recovery and speed up the process of extraction. Water is a byproduct of crude oil extraction. This water known as Produced Water is typically treated by gravitational separation where residual oil can be skimmed leaving dirty water containing salt, organics, hardness, and other compounds. This wastewater represents a large by product that requires disposal.

The produced water cannot be directly disposed of in the ocean, surface waters, or sewer due to high concentrations of dissolved solids. One option for waste disposal is the re-injection of the water into the disposal wells near where the oil was extracted. This can be an expensive and a time consuming process with transportation cost considerations. There are also issues with disposal well life and fouling of the geological formation receiving the water.

Many oil production facilities are faced with this dilemma and continue with conventional methods which can be expensive and have negative impacts on the environment. The produced water is high in alkalinity, silica, sodium, carbonate, and Total Organic Carbon. The TOC appears to be mostly made up of paraffins, waxes, and asphaltenes that are colloidal materials that do not readily separate using conventional methods. Asphaltenes tend to adsorb at water-in-crude oil interfaced to form a rigid film surrounding the interface. The asphaltenes are the heaviest and polar fraction of the crude oil, and give rise to a variety of nuisances during crude oil production and produced water treatment.

The VSEP Produced Water Treatment System

Flocculation and deposition of asphaltenes may occur when the thermodynamic equilibrium is disturbed. This can come as a result of changes in pressure and temperature as a result of compositional alterations when blending fluid streams, or due to injection of gas during oil recovery operations. The instability of the asphaltenes during equilibrium changes could cause problems with any conventional treatment method considered.

BreitBurn Energy Case

BreitBurn Energy Inc. operates a crude oil production facility in Santa Maria, California. They have implemented steam flooding in their process and are using steam generators in their operations to enhance oil production. Re-injection of produced water into the source formations has been the method of disposal. After evaluation of the VSEP technology, BreitBurn has implimented a treatment scenario where the produced water will be treated with the VSEP membrane process to make water that is clean enough to be fed to steam boilers used for steam flooding of the oil bearing formation. This invoative process will take a waste that is currently a liability and convert it to a

valuable resource source material used in the production of crude oil. The economic and political effects of this are very benenficial.
The continuous process of purchasing fresh water and disposing of the waste product seemed to be an impractical process method. They wanted to utilize this wastewater as a valuable byproduct. A process that could produce quality water with very low hardness for their steam generators from the produced water was ideal. The recycling of treated water into their process would eliminate the need for purchasing water and reduce the volume of waste disposal, but needed to meet economical requirements.

Solution

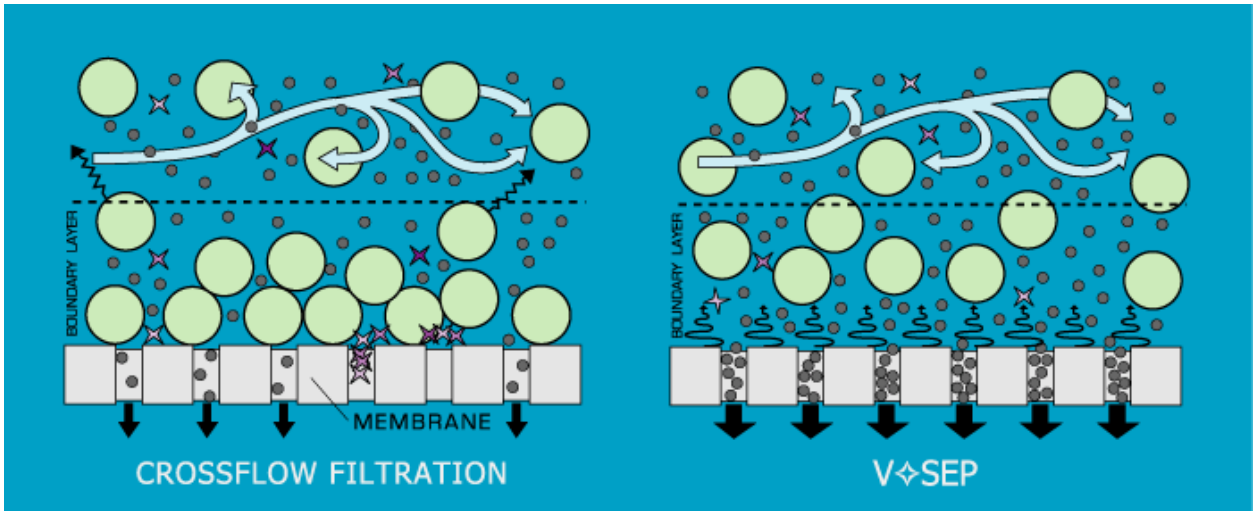
BreitBurn Energy was faced with many types of treatment processes and considered membrane separation. One solution to two problems was found in V*SEP (vibratory shear enhanced process), which is a unique membrane separation technique patented by New Logic Research. Instead of direct injection into the wells, the produced water is filtered through a nanofiltration membrane to remove oil, hardness, suspended solids, silica and other materials. A second stage conventional spiral reverse osmosis unit is used for polishing the permeate to make it suitable for boiler feed water.

The filtration scenario achieved an overall recovery of 70% of the wastewater as clean boiler feed water. Using membranes, separation is very precise with molecular weight cut off and in this case, a permeate with better quality than drinking water was produced. The concentrate was reduced to about one third the original volume, hence reducing disposal volume and costs. With VSEP incorporated in the process, chemical treatments, and disposal costs are greatly reduced. Purchased town water with softening could be completely eliminated.

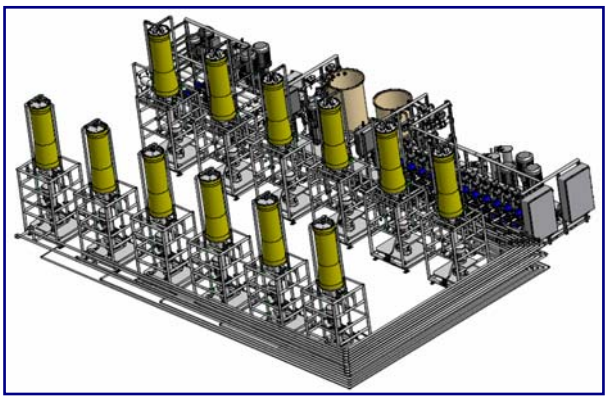
Conventional membrane systems have a tendency to foul, but VSEP has reduced fouling capabilities and can handle a very wide range of feed characteristics without affecting performance. Compared to conventional water treatment processes, VSEP is the most economical with a low capital cost and has low energy requirements. The feed material will also include small amounts of wastewater from various sources and the V*SEP is designed to handle the varying feed composition, while still consistently providing acceptable permeate quality.

This process consists of VSEP modules using nanofiltration membranes as a first stage of filtration. Then a 2nd stage of a spiral reverse osmosis membrane media is used for final polishing to make boiler feed quality water.

The system is compact and space efficient. VSEP comes in a variety of sizes and the number of units required is calculated based on process flow. Being a modular system, the ability to add additional machines is simple. Filter packs can be changed and different membranes can be used on the same machine for a variety of applications. This is an added benefit for BreitBurn Energy due to the fact they will be expanding the system in the future as more steam generators are added.
Conventional membranes are limited in their abilities. Particles can become lodged in the membrane pores causing fouling. This will cause



reduced flow and permeate recovery as well as frequent cleanings. A laminar boundary layer will form at the surface of the membrane resulting a formation of a barrier for the permeate and additional fouling. By applying a shear force to the surface of the membrane these problems can be decreased or even eliminated.



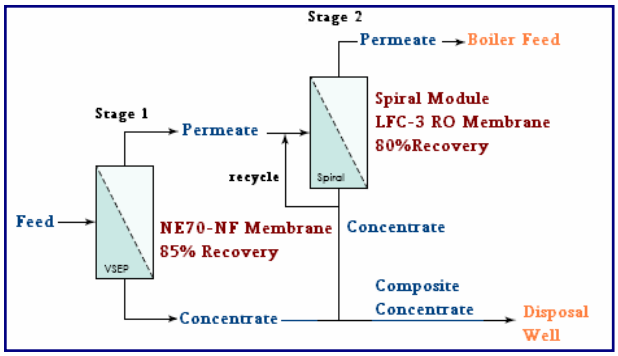
The VSEP is a vibrating plate and frame membrane system that is able to produce economical flow rates and reliability with fouling resistance due to the vibration. The membrane vibrates at a 3/4" displacement at 55Hz. The stagnant boundary layer that forms at the surface of the membrane is disrupted as a result of the vibration and applied shear force. The vibration keeps the turbulent flow at the surface of the membrane allowing molecules to continue movement away from the surface, avoiding fouling and allowing the smaller particles to pass through the membrane.

This unique system has many advantages over conventional membranes and also other technologies for the same application. VSEP can process much higher concentrations of feed and has no limits with regard to feed water quality. In the case of BreitBurn Energy, the feed is mainly composed of produced water, but will also include small amounts of wastewater from a variety of sources. The VSEP is designed to handle this variation in feed quality without sacrificing product quality or throughput. VSEP can handle very high levels of suspended solids, Silica, and many other problematic materials.

Process Conditions

The VSEP installation is designed to achieve 85% recovery in stage 1 using nanofiltration membranes and then 80% recovery in stage 2 with the spiral RO modules. The overall recovery is about 70%. Since disposal wells remain an option for reject disposal, maximum overall recovery was not a primary objective. Higher recoveries can be allowed for by adding more filtration equipment. A VSEP system can even be designed for zero-liquid discharge if needed.

The feed to the VSEP contains 25,900ppm of Total Dissolved Solids and 870ppm of hardness. The final permeate after two stages of filtration has a non-detectable amount of hardness and water quality that is suitable for boiler feed water. VSEP nanofiltration is used to remove all of the bad actors that would not be suitable for feed to a conventional RO spiral system. VSEP modules are modular and can be used in parallel for any size of flow rate. The following diagram shows the process scenario used in this case employing two stages of membrane filtration.



New Logic has had experience working with various produced waters in California, the North Sea, Latin America, and Alberta's Oil Sands and has been able to continually improve on process variable conditions. Making steam generator feed is one possible use of the VSEP technology. Treating the produced water for surface water or ocean discharge is another possible use of VSEP. In such cases, the 2nd stage membrane system would not be needed and a single stage of VSEP filtration could be used to treat the wastewater for discharge. VSEP is quite capable of meeting the 30 ppm Oil limit for offshore disposal.

Economic Value

New Logic's VSEP system provides an alternative approach for produced water treatment. In a single operation step, VSEP will provide ultra-pure water and also reduce BOD, COD, TSS, TDS and color to provide a high quality filtrate. The addition of VSEP can eliminate conventional treatment equipment including the need for chemical treatments and disposal wells.

Deep well injection is used for many difficult to deal with waste streams. However, the option of Deep Well Injection is limited by the underlying geology. Any deep well discharge must be protected against mixing with drinking water aquifer supplies. The permitting process can also be long and arduous. Usually deep well injection is a last resort since it is more difficult and time consuming than other methods of disposal.

Costs for disposal wells are mostly related to permitting, drilling, and logistics. Very often, disposal well locations are not in the same area as where the wastewater is generated. This means that brine effluent would need to be piped and pumped dozens of miles to a suitable location with porous rock formations. There are cost savings if the use of disposal wells can be reduced or eliminated.

A VSEP system can be installed and operated for about the same cost as purchasing town water and then treating it using chemical methods to make boiler feed water. The economic cost savings would come from reduction in disposal well requirements. There are many other benefits where applying economic value is difficult. First, recycling wastewater would make an operation self sufficient and not dependant on local water supplies. Also, there can be many public relations gains achieved by presenting the recycling process as an environemntally friendly process.

Other VSEP Applications

New Logic has a great deal of experience when it comes to treating oilfield wastewater and has installed industrial equipment for similar industrial applications

- Filtration of Used Crankcase Oil
- Dewatering of oily wastewater from haulers
- Recycling of oil based coolants
- Stripped Sour Water
- Desalter Effluent
- Glycol Recovery
- Tank Bottoms Treatment
- Tank Washdown Water
- Truck and Bus Washwater

Pilot Testing

Each application that comes to New Logic goes through rigorous tests and each system conditions are customized. The process begins with an initial feasibility test using lab scale VSEP machines. An important characteristic of VSEP is that just about any membrane on the market can be cut and inserted into the VSEP. A variety of membranes are tested based on the application and the best membrane continues to test different variables including pressure, temperature, pH, % recovery and others.

Further testing is completed onsite with pilot machines. New Logic works with a wide range of applications from all types of wastewater to even hog manure and works to meet each individual application's objectives.

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 VSEP 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.

Today's Series i (Industrial) VSEP is a full scale model and comes in sizes ranging from 100 Square Feet to 2000 Square Feet. These units are modular

and can be used in parallel or in series. Successful industrial VSEP systems are in place world wide including Europe, Central Asia, Southeast Asia, Australia, South America, Canada, Mexico, and of course here in the United States. New Logic offers a strong engineering staff to assist customers in the design, development, and testing of their filtration systems. After outgrowing two previous locations in the last ten years, New Logic is now located in a 40,000 square foot manufacturing building in Emeryville. The plant has extensive equipment and machinery for manufacturing nearly all the VSEP parts. Manufacturing, assembly, and testing of all equipment takes place at this site. Systems and procedures are in place and geared towards high standards of quality control and have met the acceptance criteria of stringent applications such as nuclear waste processing.

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 contact:

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