

## Ask Tom! Column

### Petroleum Wastewater - Desalter Case Study

Guest article by Greg Johnson, New Logic Research



New Logic Research has developed an innovative and rugged ultrafiltration membrane system for the treatment of desalter effluent. In the past, desalter effluent has been something that a refinery has just put up with and tried to manage as best it can. Now by utilizing the proprietary VSEP Filtration System, desalter effluent can be treated and mitigated at the source.

#### Crude Oil Basics

Crude oils are complex mixtures containing many different hydrocarbon compounds that vary in appearance and composition from one

oil field to another. Crude oils range in consistency from water to tar-like solids, and in color from clear to black. An “average” crude oil contains about 84% carbon, 14% hydrogen, 1%-3% sulfur, and less than 1% each of nitrogen, oxygen, metals, and salts. Refinery crude base stocks usually consist of mixtures of two or more different crude oils.

Crude oils are also defined in terms of API (American Petroleum Institute) gravity. A crude with a high API gravity are usually rich in paraffins and tend to yield greater proportions of gasoline and light petroleum products. Crude oils that contain appreciable quantities of hydrogen sulfide or other reactive sulfur compounds are called “sour.” Those with less sulfur are called “sweet.”

All crude oils are assayed and valued depending on their potential yield. Crude Oil with low assay numbers is referred to as “Opportunity Crude”. This type of oil will be more difficult to process due to higher levels of contaminants and water. This type of crude will typically give desalter equipment the most trouble and require the greatest skill of the operator.

#### Desalting - The First Step in Crude Oil Refining

Desalting and dewatering of crude oil upstream of the crude distillation unit is a key process operation for the removal of undesirable components from crude oil before it reaches any of the major unit operations. The operation of a desalting system can be very challenging due to changing process variables. At best, it is a process of measuring trade-offs and compromises.

A delicate balance must be maintained while controlling mixing intensity, wash water quality, chemical demulsifier feed and other parameters that can provide optimal salt removal. On one hand the quality of the crude overflow must be within specific standards and on the other hand the under-carry must not be so potent that it compromises the system’s dehydration abilities or fouls up downstream wastewater treatment. New legislative demands placed on effluent water quality present the operator with a difficult challenge. Optimizing the desalting process under constantly varying conditions is a key ingredient to success of the entire refinery operation.

The main function of the Desalter is to remove salt and water from the crude oil. However, many other contaminants such as clay, silt, rust, and other debris also need to be removed. These can cause corrosion and

fouling of downstream equipment when deposited on heat transfer surfaces. Also, there are metals that can deactivate catalysts used in the process of refining.

## Desalter Theory

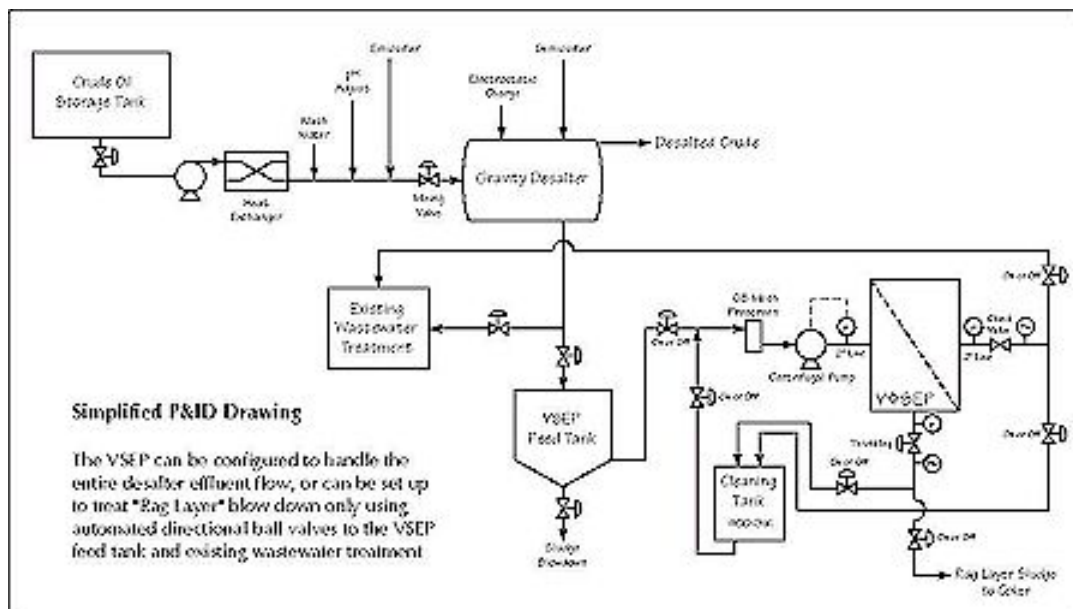
The Desalter removes contaminants from crude oil by first emulsifying the crude oil with chemicals and wash water to promote thorough contact of the water and oil. The salts containing some of the metals that can poison catalysts are dissolved in the water phase. After the oil has been washed and mixed as an emulsion of oil and water, demulsifying chemicals are then added and electrostatic fields are used to break the emulsion. Desalters are sized to allow the water and oil to settle and separate according to Stoke's Law.

In addition, solids present in the crude will accumulate in the bottom of the desalter vessel. The desalter must be periodically washed to remove the accumulated solids. A "mud washing" system is installed in the bottom of the vessel to periodically remove the solids. Mud washing consists of recycling a portion of the desalter effluent water to agitate the accumulated solids so that they are washed out into the effluent water. These solids are then routed to the wastewater system.

Desalter effluent or "undercarry" is a combination of many things including the mud wash done at periodic intervals, produced water that came with the crude, and the brine wash water resulting from the dilution and removal of salts and other contaminants.

## Desalter Process

To accomplish desalting, the crude is first preheated to 120-150°C with heat exchangers in order to reach the required viscosity level normally in the range of 5-15 centi-stoke. The temperature is limited by the vapor pressure of the crude-oil feedstock. About 2-6% wash water is metered in ahead of the desalter as an extraction agent to help dissolve salts and sediments. Intense mixing then takes place over a mixing valve.



Once in the pressurized desalter vessel, the salts and sediment settle with wash water and tend to form emulsions. The wash water is separated by electrostatic precipitation using de-emulsifiers and acid. The salts that are removed are mainly chlorides and carbonates. They can cause corrosion and fouling downstream in the heat exchangers, furnaces, and distillation units, if not removed.

Electrical desalting is the application of high-voltage electrostatic charges to concentrate suspended water globules in the bottom of the settling tank. Surfactants are added only when the crude has a large amount of

suspended solids. Other less-common processes involve filtering heated crude using diatomaceous earth and chemical treatment and settling. Ammonia is often used to reduce corrosion. Caustic or acid may be added to adjust the pH of the water wash.

Wastewater and contaminants are discharged from the bottom of the settling tank to the wastewater treatment facility. The desalted crude is continuously drawn from the top of the settling tank and sent to the crude distillation tower. A properly performing desalter can remove about 90% of the salt in raw crude.

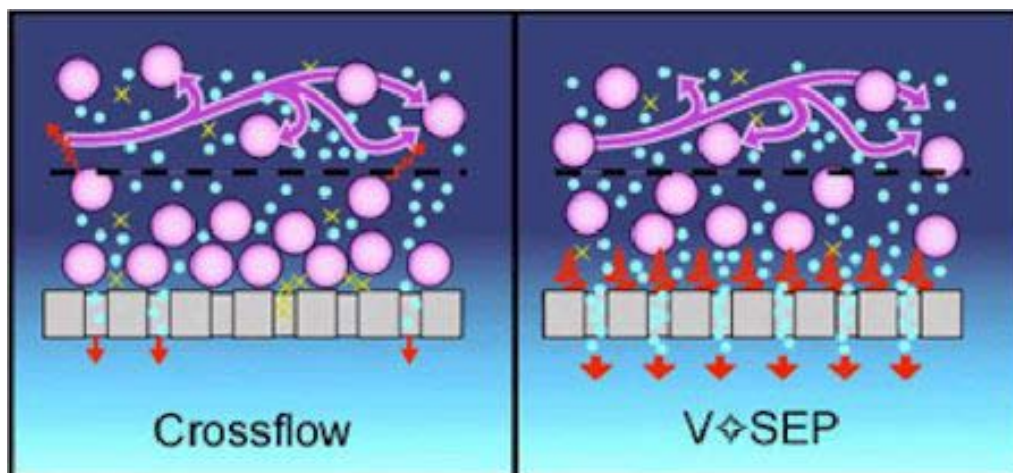
## Refinery Wastewater

The desalter effluent is a major source of contaminated wastewater and a source of hydrocarbons as oil under carry to the extent that emulsions are not completely broken. Oil under carry can be the single largest source of oil losses to the wastewater treatment system. Reduction in the amount of Oil in the undercarry not only reduces sewer loadings but also recovers valuable raw material that would otherwise be lost.

Rates vary with the water content of the crude oil and the degree of difficulty in desalting the crude, but a representative rate would be around 2-2.5 gallons of wastewater per barrel of crude oil feed to the unit. Desalter water contains salt, sludge, rust, clay, and varying amounts of emulsified oil (oil under carry). Depending on the crude oil source, it may or may not contain significant levels of hydrogen sulfide (H<sub>2</sub>S), ammonia, and phenolic compounds. Relatively high levels of suspended and dissolved solids are usually observed.

## VSEP Membrane Filtration - Enabling Technology for Desalter Effluent

The most fundamental process in a refinery operation that of separation. Since the desalter is the first step in refining of crude oil, a bottleneck at the desalter is a bottleneck for a billion-dollar refinery asset. In addition, the desalter will be the predominant source of wastewater in a refinery and an upset in the desalter can cause upsets in the wastewater treatment plant and put that system at risk of not meeting discharge requirements. The current methods of desalter operation are focused on coping and adjusting with the variations in process variables that are inevitable. The treatment method involves a crude gravity separator combined with chemical manipulation and operator expertise. This process is antiquated and less than desirable from a redundancy and processing point of view.



The VSEP polymeric membrane filtration process offers an innovative, precise, and utterly redundant separation technique for crude oil refining and processing. In addition to enabling a range of very fine selective separations, use of membrane filtration results in reduced capital, chemical, operating, and energy-consumption costs. The potential for economic benefit to the user industry is revolutionary.

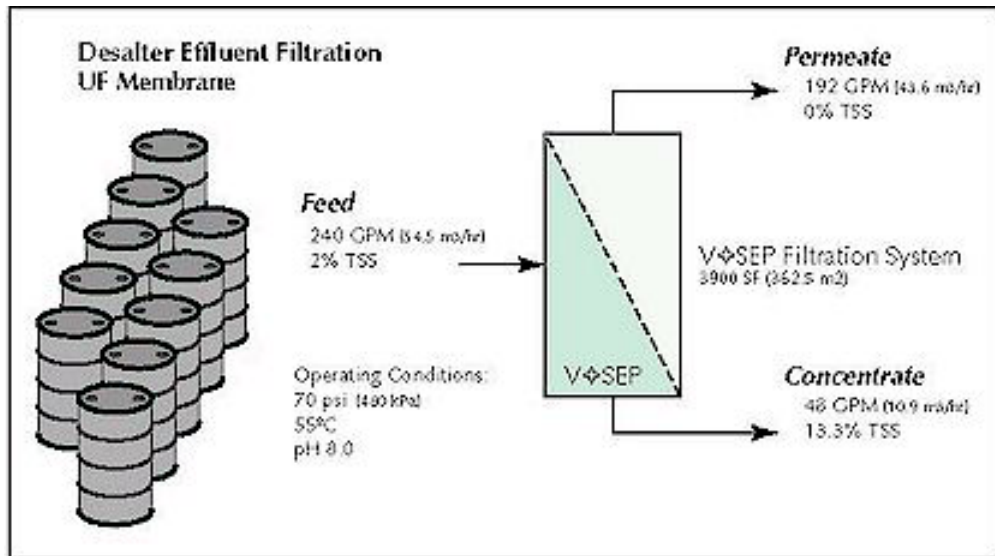
## VSEP Desalter Treatment Process Options

There are a number of possible scenarios for filtration. During the evacuation of the desalter undercarry, the settled solids will be washed out of the system to prevent build up. When this happens some of the rag layer emulsion comes with it. This blow down is what can give conventional chemical wastewater treatment plants trouble. The VSEP can be set up to handle the entire flow of the desalter effluent including both the briny salt water as well as the modulating rag layer blowdown. Or, by using automated valves, the VSEP can be configured to handle only the rag layer blow down.

If the VSEP will handle the entire desalter effluent flow, the desalter is set to a continuous mud wash process to even out the solids loading in the feed to the VSEP. Then the VSEP will dewater this effluent and send a concentrated sludge to the Coker. If the VSEP will only handle the rag layer blowdown, the mud wash operator controls destination valves accordingly. While the desalter is just draining salt-water effluent, the waste will be sent to the existing treatment plant. Then just prior to a mud wash, destination valves will configure to feed the desalter effluent to the VSEP. After the mud wash, the valves revert back to the original position feeding the wastewater treatment plant.

## Case Study Process Conditions

The oily wastewater is fed to the VSEP treatment system at a rate of 240 gpm. The VSEP system will monitor tank level and will adjust based upon demand. The VSEP feed tank acts as a primary settling tank. It is cone bottomed and heavy solids settle quickly where they are purged. The feed to the VSEP is taken out of the side of the tank to eliminate excessive maintenance cleaning of a protective 60 mesh pre-screen to the VSEP. As the system initiates, a feed pump will spin up to a pressure of 70 psig. Then a modulating valve will throttle the flow of the reject to a rate that will produce the desired concentration of suspended solids.



Three industrial scale VSEP units, using ultra-filtration membranes are used to treat the 240 gpm process effluent. The concentrated reject stream is at a concentration of about 13.3% TSS and is sent to the Coker for recovery of the oil and hydrocarbons. VSEP generates a permeate stream of about 192 gpm which is sent on to the existing wastewater treatment plant. The permeate contains less than ~ 1 mg/L of total suspended solids (TSS), and reduced levels of total dissolved solids (TDS). Membrane selection is based on material compatibility, flux rates (capacity) and concentration requirements. In this example, the TSS reduction is well over 99% while the oily waste is concentrated from a starting feed of 1.5-2% to a final concentrate of 13.3% by weight.

## **Benefits of VSEP when used for Desalter Effluent**

### Redundancy

The VSEP is installed as a side stream to the desalter effluent. It is used on a demand basis and will initiate automatically based upon tank level. It offers many kinds of redundancy options in operation that are very important to refinery operations. First, the VSEP system can be bypassed completely if desired and the desalter effluent will be treated in the same manner as it is now. Or the VSEP can handle the entire desalter flow and help to take the load off of the existing wastewater treatment, thus increasing its capacity and safety margin when it comes to discharge. VSEP units are modular and easy to install in parallel for complete redundancy.

### Skill of the operator

The rag layer blow down is the primary cause of process upsets and the manipulation of this process requires a very skilled operator or group of operators who cannot afford to make mistakes. The normal salty water discharge from the desalter is relatively benign and can be handled easily by existing processes. The fact that the quality of the crude changes and that the blow downs are done at specified intervals means that this process is a constant game of tweaking and cajoling. Installation of the VSEP with the set purpose of processing the problematic rag layer blowdown removes this process headache from the effluent operator's daily chores. When VSEP is installed, the frequency of blowdown, the effectiveness of the demulsifiers, and the variations in the crude are unimportant and no longer pose a process upset threat.

### Debottlenecking the facility

Since the desalter is the first step in refining of crude oil, it is critical that this piece of equipment be consistent and reliable. Because oil is superheated and pressurized during refining, it is not a process that you can just turn off with a switch. Shut downs can take hours or days to complete. In addition, the profitability of the refinery depends on getting maximum use out of the refinery asset and personnel on staff. Process upsets cannot be tolerated. The desalter has been identified as a very significant threat for bottlenecking the entire refinery operation including the refining of oil and the wastewater treatment that comes from it. Installation of VSEP can mitigate or eliminate the possibility of desalter bottleneck. VSEP is a redundant and effective tool that can be used to reduce process risk.

### Reduce the load on wastewater treatment

The desalter can be the primary source of wastewater to the wastewater treatment plant. The desalter operator must constantly be careful about the discharge of the desalter so that the treatment plant is not overloaded or unable to handle the hazardous materials that come from the desalter. Sometimes this can mean lesser quality desalted crude is produced as a trade off to not swamping the treatment plant. Desalter effluent is the primary source of oil to the treatment plant.

Many times the existing wastewater treatment plant is at capacity and the amount of overdesign and safety factor is marginal. VSEP is a very effective tool that can be used to control the load on the treatment plant. Since the VSEP can take the rag layer blow down out of the wastewater loop and send it to the Coker, this alone reduces the load significantly. The VSEP can also be configured to handle the entire desalter effluent further reducing the load on the treatment plant.

The VSEP can also be configured to handle the desalter effluent completely and bypass the existing treatment plant. These options give process engineers ultimate ability to maximize the use and capacity of the existing wastewater treatment facility.

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**Welcome to Ask Tom!**, a monthly column by our resident water treatment guru, Tom Keenan of National Environmental Services Agency (NESAs). Tom addresses the issues that bug you the most. And Tom knows!! With 35 years experience in providing environmental support services to public and private sector clients on a wide range of environmental issues.

Help others by posting your comments, suggestions and experiences with water or wastewater treatment or any other concerns you may have on our On-Line Help Forum. For past **Ask Tom!** Articles, visit the **Ask Tom! Archive**.

Guest articles for the **Ask Tom!** Column are always welcome, for more information please contact Tom Keenan directly at his email address: [info@nesa.ie](mailto:info@nesa.ie)

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