

REPLACEABLE SKIN LAYER

RSL MEMBRANES™

HIGH INTENSITY FROTH FLOTATION

(HIFF)

THE APPLICATION OF IONIC SURFACE CHEMISTRY
TO MANIPULATE THE ELECTRIC DOUBLE LAYER
OF COLLOIDS



2017 FINALIST

THE MOST DISRUPTIVE SUSTAINABLE TECHNOLOGY
IN THE WORLD
- Patent Protected



"2019 - CELEBRATING 39 YEARS OF BUSINESS."

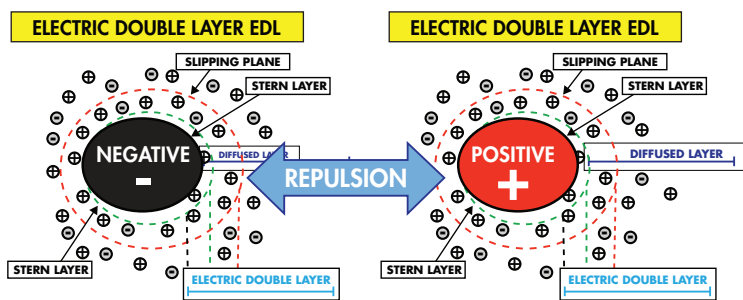
dbe DAVID BROMLEY ENGINEERING LTD.

DBE has developed a new and disruptive water treatment technology to replace existing filtration and oil separation technology resulting in a 10 fold improvement in capacity, 90% reduction in energy and 25 to 40% reductions in capex and opex. The technology, known as Nanoflotation, was a finalist in the 2017 California based Katerva awards as the most disruptive sustainable technology in the world. Also after third party peer review, the Chinese Ministry of Environmental Protection selected Nanoflotation as the one of the top 100 environmental technologies in the world.

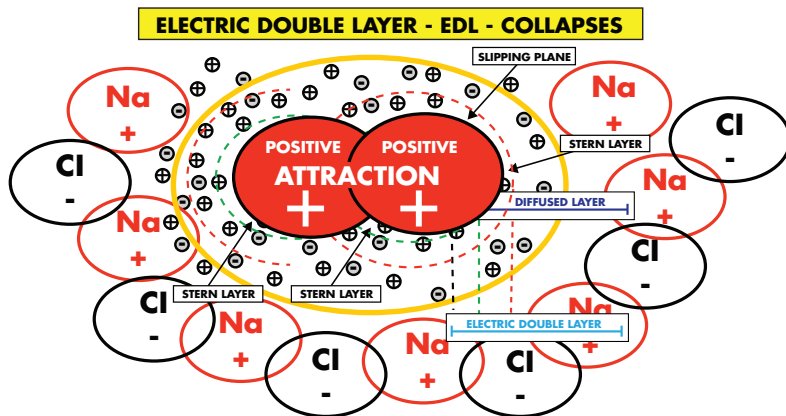
The rapid separation of solids and oil from water is a result of the ability to manipulate the nano-environment and the electric double layer (EDL) around colloids. The well-known DLVO theory explains the ability to simultaneously repulse and attract colloidal particles.

The charge on a colloidal solid does not cause a solid to repulse or attract. It is the EDL that causes repulsion or attraction. Once the ionic environment around the colloidal solids increases in the ionic charge, the EDL collapses and the colloidal solids attach to each other or to other surfaces.

The EDL is causing + and - particles to repulse.



The increased ionic charge causes colloids to attract.



The surface chemistry defined in Nanoflotation is applied to two common water treatment processes; Flotation and low pressure membranes. For flotation, the ionic environment is manipulated using a froth created by a highly charged (ionic) surfactant. For membranes, a charged replaceable powder skin layer is used in lieu of the skin layers on conventional membranes.

The DLVO Theory - the basis for filtration in the RSL Membranes™



DLVO THEORY

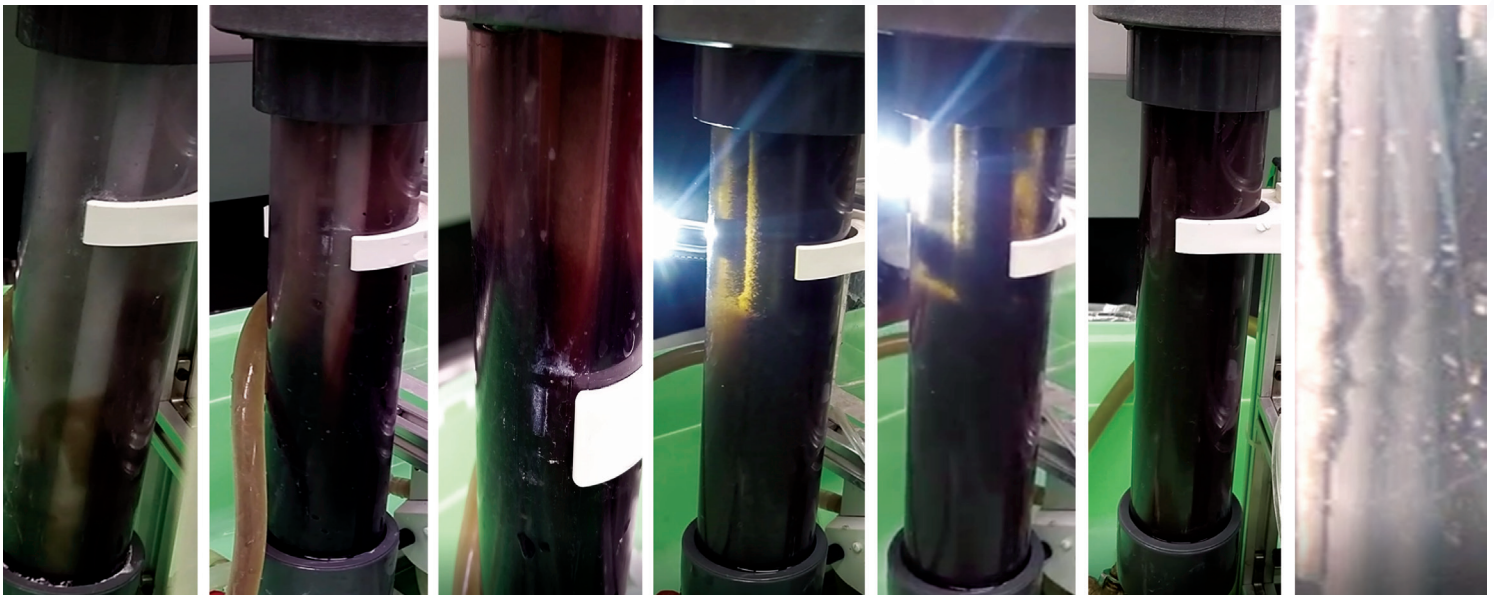
This photograph shows a river that has natural fresh water from snow melt solids in the mountains. The Water has a low ionic concentration and solids in suspension. The river enters the ocean where there is a high ionic environment due to the NaCl. As a result, the solids separate from the water. When the solids are in suspension the Electrical Double Layer (EDL) around the colloid solid is strong and repulsion forces are strong. When the ionic strength of the local environment increases, the EDL collapses and attraction forces (van der Waal) become dominant.

Application examples of the technology will help define the robustness, and disrupting character of Nanoflotation.

The technology is well proven. Waters containing very high suspended/colloidal solid content and emulsified oil are easily treated. The first one year evaluation of the technology was undertaken through a third party independent review process. Twelve technologies were originally selected and were then narrowed to two technologies for field testing. The two technologies were Nanoflotation and a Ceramic membrane marketed by Veolia, the world's largest water treatment utility operator. It was through this testing that the Replaceable Skin Layer (RSL) Membranes™ were rated as having a 10 fold improvement in capacity compared to the conventional ceramic membranes.

For example, where conventional membranes require 1000 m2 of membrane area to treat a specific water, the area required for RSL membranes™ is 100 m2. The material reduction has allowed for the economic application of exotic membrane materials. This is important as it has allowed RSL Membranes™ to be used in high temperature applications (up to 600 C), such as steam and hot oil operations.

THE POWER OF SIMULTANEOUS REPULSION AND ATTACHMENT ELECTRIC DOUBLE LAYER (EDL) AND THE DLVO THEORY



SAGD
Produced
Water
Example 1 -
after 1 minute

SAGD
Produced
Water Example
1 - after 5
minutes

SAGD
Produced
Water Example
1 - after 10
minutes

SAGD
Produced
Water Example
2 - after 30
minutes

SAGD
Produced
Water Example
2 - after 45
minutes

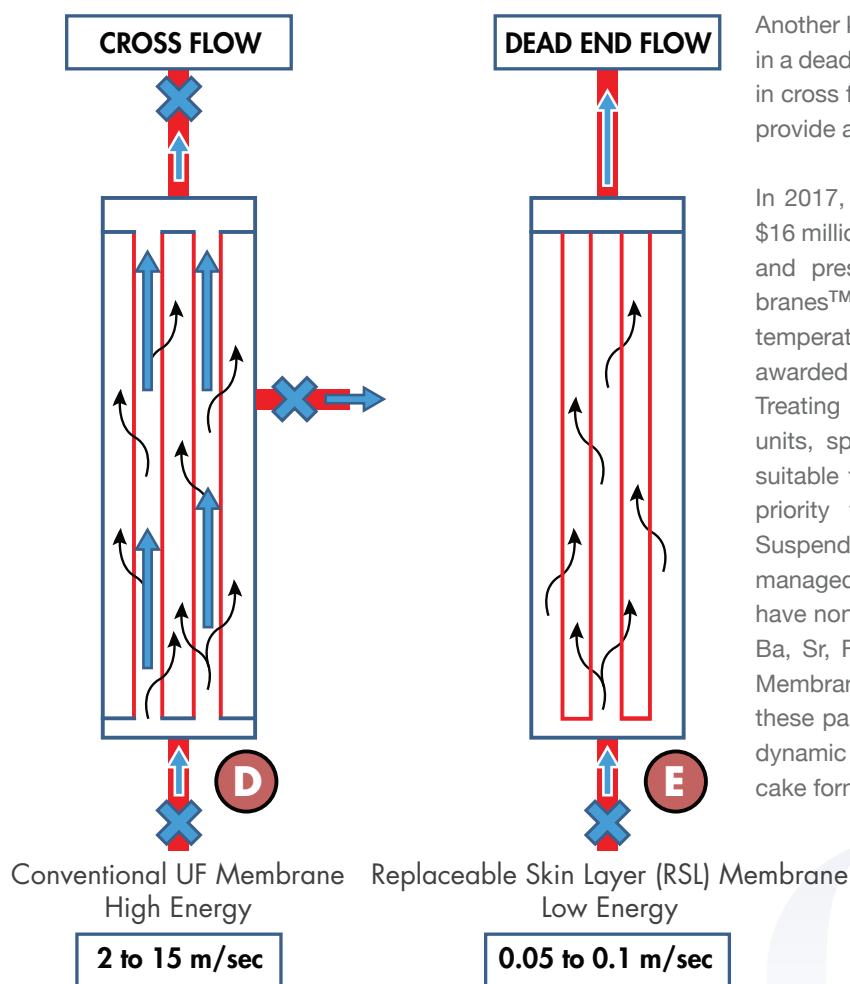
SAGD
Produced
Water Example
2 - after 60
minutes

Rubber
Waste Water -
during Backwash
after 9 hour
filtration cycle

In Example 1 (far left) the produced water is introduced to the RSL™ Membrane. The highly charged white powder skin layer is visible on the surface of the stainless steel membrane tube. The velocity vectors of the flow of raw water and the white powder material are sufficient to hold the white powder on the surface of the membrane tube. The colloidal solids entering the tube, however, have a much slower vector velocity towards the tube because of the repulsion force from the white powder skin layer. As a result, the solids to be removed from the water, do not cake onto the surface of the powder skin layer.

This is evident in Example "1" @ 5 minutes and 10 minutes as well as in Example "2". Observing the colloidal solids shows that they are being repulsed from the surface of the RSL™ membrane™ and actually create a sludge layer on the lower part of the column. Because the RSL™ Membrane™ operates as a dead end filtration with no crossflow, the solids build up in the concentrate (upstream of the RSL™ Membrane skin layer).

Eventually, as shown in Example 2 at 60 minutes, the membrane housing does not have a distinctive sludge layer. The colloidal solids continue to concentrate in the housing. In some tests, these solids have concentrated as high 3% (30,000 mg/l) and emulsified oils as high as 280,000 mg/l. Eventually the solid levels become so high in the concentrate, the colloids penetrate the powder skin layer. The EDL on the colloids collapses and the solids attach to the white powder within the RSL™ Membrane™ skin layer. The skin layer grows in thickness as shown in the rubber waste water example (far right). This causes the trans membrane pressure (pressure across the membrane) to rise. Once the pressure reaches 1 bar after 6 to 15 hours of filtration, the skin layer is replaced and the filtration cycle starts over. In 4 minutes the expended skin layer is removed and a new skin layer is applied.



Another key design benefit of RSL Membranes™ is that they operate in a dead end filtration mode thereby saving the energy typically used in cross flow membranes. This is the key reason, RSL Membranes™ provide a 90% reduction in energy consumption.

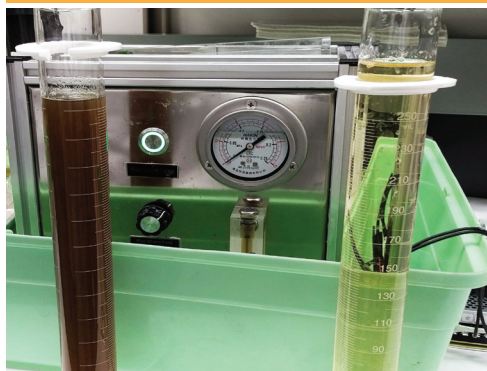
In 2017, the Canadian Licensee of the technology was awarded a \$16 million contract to commercially treat water at high temperatures and pressure for oil sands operations. Specifically, RSL Membranes™ will be used to separate silica from produced water at temperatures of 130 C and 3 Bar pressure. The contract was awarded after three independent evaluations of the technology. Treating waters at high temperature is important to many process units, specifically processes that rely on steam. To create water suitable for human consumption or high quality process water, the priority treatment is the removal of suspended solids. Total Suspended Solid (TSS) concentrations as high as 20,000 ppm can be managed by the RSL Membranes™. Typical effluents/permeate will have non-detect TSS. For parameters that are dissolved (Si, Ca Mg, Ba, Sr, Fe) but can be precipitated into a discrete solid, the RSL Membranes™ provide a simple one component method to reduce these parameters. Note: RSL Membranes™ are not a filter cake or dynamic membrane technology. The technology relies on no filter cake forming.

BOILER BLOWDOWN WATER WITH HIGH SILICA



The reactive Silica that is dissolved is converted to a solid using an oxide chemistry and then removed by the RSL™ Membranes. The feed to the membrane has TSS levels >1000 mg/l

SILICA SOLIDS IN BOILER BLOWDOWN OR EVAPORATOR BLOWDOWNS



RSL™ Membrane quality remains consistent through filtration cycle. Typically zero TSS in effluent. Trans membrane pressure remains very low. In this example the TMP had not registered after 2 hours of filtration. Backwash of the skin layer occurs once the TMP reaches 1 Bar. Flux rate 350 l/mh

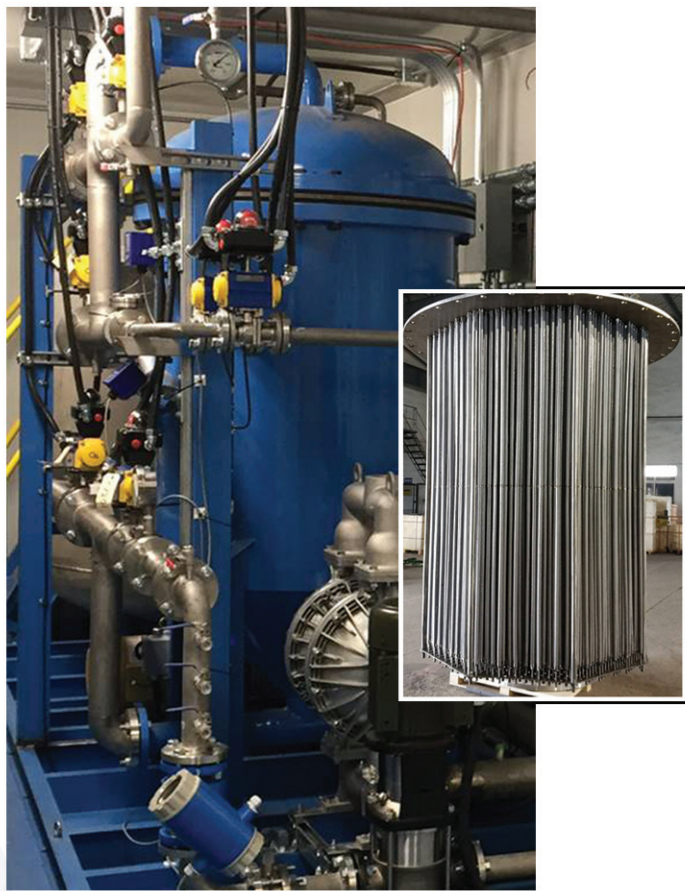
BUILD UP OF SOLIDS ON THE UPSTREAM SIDE OF THE RSL MEMBRANES™



As the filtration continues the solids concentrate in the membrane housing to levels > than 10% TSS but effluent quality remains consistent.

REPLACEABLE SKIN LAYER RSL™ MEMBRANES

Typical commercial RSL™ Membrane tube bundle with housing.



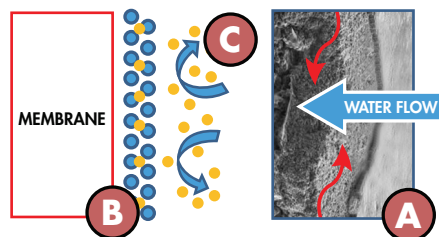
A commercial RSL Membranes™ is a bundle of Polymeric, stainless steel or Titanium tubes.

The tube surface area is designed for a typical flux rate of 350 litres/m²/hr (lmh) but depending on TSS loading (high =1000-2000 ppm and low=100-200 ppm), the design could be as low as 200 lmh to 800 lmh respectively. In addition the type of solid impacts the flux rate. The design depends on the repulsion and attraction of the solid to the RSL powder.

The length of the filtration run can vary from 2 hours to 30 hours. Because the RSL Membranes™ operates in a dead end filtration mode the solid concentration (TSS) on the upstream side of the membrane builds up to 14000 to 20000 ppm. This concentration level results in a transmembrane delta pressure of approximately 70 kpa (10 psi). Where the RSL Membranes™ is being used for the separation of emulsified oil, the concentration of oil on the upstream side of the membrane will be approximately 28% (280,000 ppm).

REPLACEABLE SKIN LAYER (RSL)

Filtration does not rely on the development of a filter cake on the surface of the membrane. As water passes through the replaceable skin layer (RSL) media, the colloidal solids are repulsed at the surface of the RSL. Eventually some colloids will enter the RSL. The electric double layer will collapse and the colloidal solids will attach to the surface of the powder media inside the RSL layer. With the repulsion and attachment of colloids inside the RSL layer, no filter cake develops on the surface of the RSL layer.



REPLACEABLE SKIN LAYER MEMBRANE

Stainless Steel, Ceramic or Polymeric Membrane Material with 1u to 7u pore size. This surface is the substrate for the Replaceable Skin Layer (RSL)

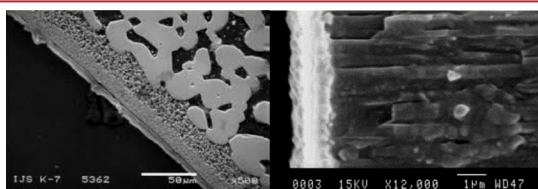
OIL REMOVAL FROM REFINERY COKER PROCESS



Right to Left: Raw Water /Oil : After Flotation - free oil removed - emulsified oil 2000 mg/l : After one pass of RSL Membranes™ Oil 29 mg/l, NTU 0.55. Flux rate is 375 lmh

After RSL Membrane Water Sample

Once the transmembrane pressure reaches 70 kpa, the RSL powder layer is removed by backwashing which takes about 2 minutes. In addition the concentrate on the upstream side of the membrane is sucked to a concentrate tank to ensure efficiency in managing the sludge. The use of the replaceable skin layer eliminates the problem with conventional membranes (i.e. cleaning the skin layer attached to the membrane substrate)



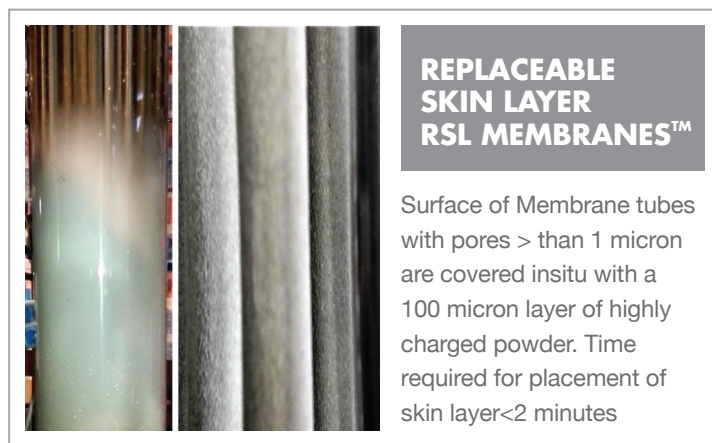
CONVENTIONAL LOW PRESSURE MEMBRANES

(Micro or Ultrafiltration membranes)

conventional attached skin layer with typically 0.01 to 0.1 micron pore size- skin layer needs to be cleaned and is not replaceable

TYPICAL APPLICATIONS OF RSL MEMBRANE TECHNOLOGY

Once the replaceable skin layer is removed, the membrane housing is refilled with clean water and the RSL powder is added to the the memebrane tubes by injecting a slurry into the membrane housing. The powder coats the surface of the tube causing the RSL skin layer.



ALUMINUM PRECIPITATE FROM AN ALUMINUM ETCHING PLANT.



RSL Membrane™ quality remains consistent through filtration cycle. Typically zero TSS in effluent. Trans membrane pressure remains very low. In this example the TMP had not registered after 2 hours of filtration. Backwash of the skin layer occurs once the TMP reaches 1 Bar. Flux rate was 325 l/mh

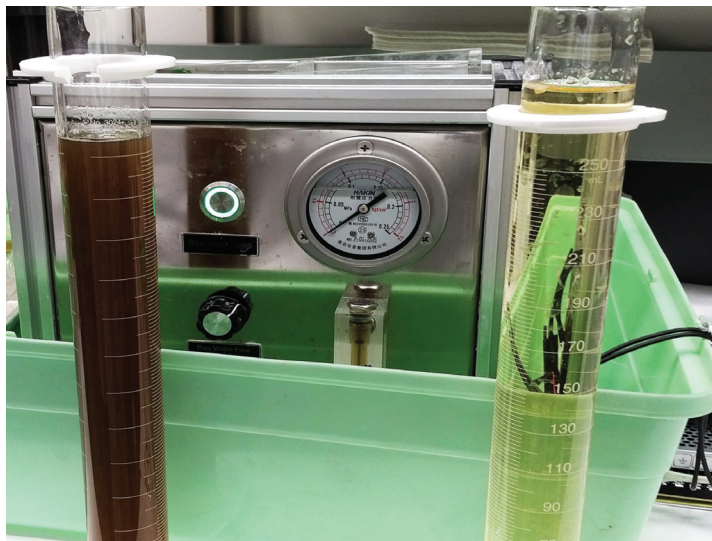
ALUMINUM ETCHING		RAW	RSL FILTERED	
Wastewater			Sample 1	Sample 2
Total Aluminum (Al)	mg/l	200	0.036	0.032
Total Calcium (Ca)	mg/l	150	31	32
Total Copper (Cu)	mg/l	7.0 (1)	0.025	0.030
Total ron (Fe)	mg/l	200	<0.60	0.28
Total Magnesium (Mg)	mg/l	350	180	240
Total Phosphorus (P)	mg/l	530 (1)	3.3	35
Total Suspended Solids (TSS)	mg/l	2350	0	0

PRODUCED WATER FROM CONVENTIONAL OIL FORMATION IN ALBERTA CANADA



TDS < 200,000 mg/l ,very high amounts of Magnesium resulting in TSS levels >5000 mg/l in the feed water to the RSL Membrane™. Permeate quality remained consistent through out filtration cycle. Trans membrane pressure increase to 25 kpa in 1 hour. TSS solid concentration in the Membrane housing was >20% at the time of backwash (TMP at 1bar). Flux rate 220 l/h

SILICA SOLIDS IN BOILER BLOWDOWN OR EVAPORATOR BLOWDOWNS



RSL Membrane™ quality remains consistent through filtration cycle. Typically zero TSS in effluent. Trans membrane pressure remains very low. In this example the TMP had not registered after 2 hours of filtration. Backwash of the skin layer occurs once the TMP reaches 1 Bar. Flux rate 350 l/h

SCRUBBER WASTEWATER FROM REFINERIES



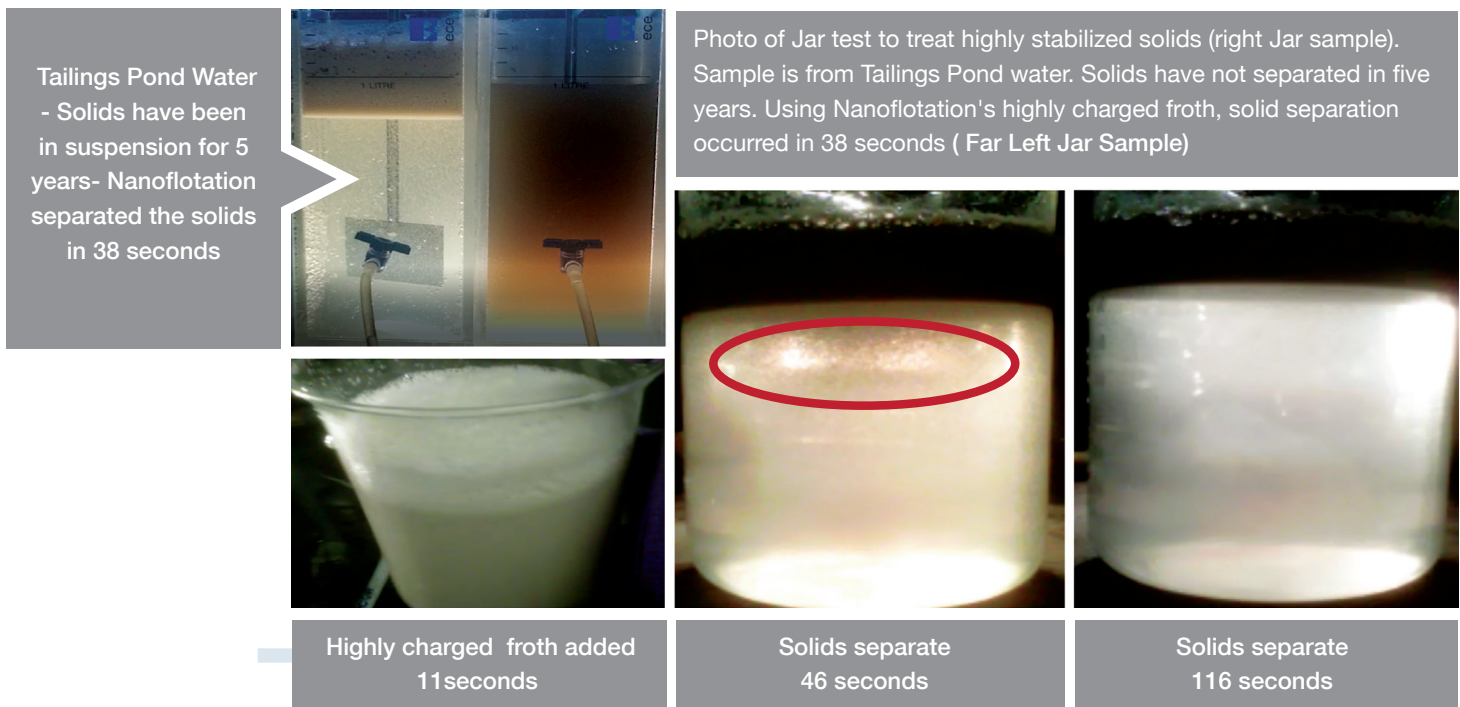
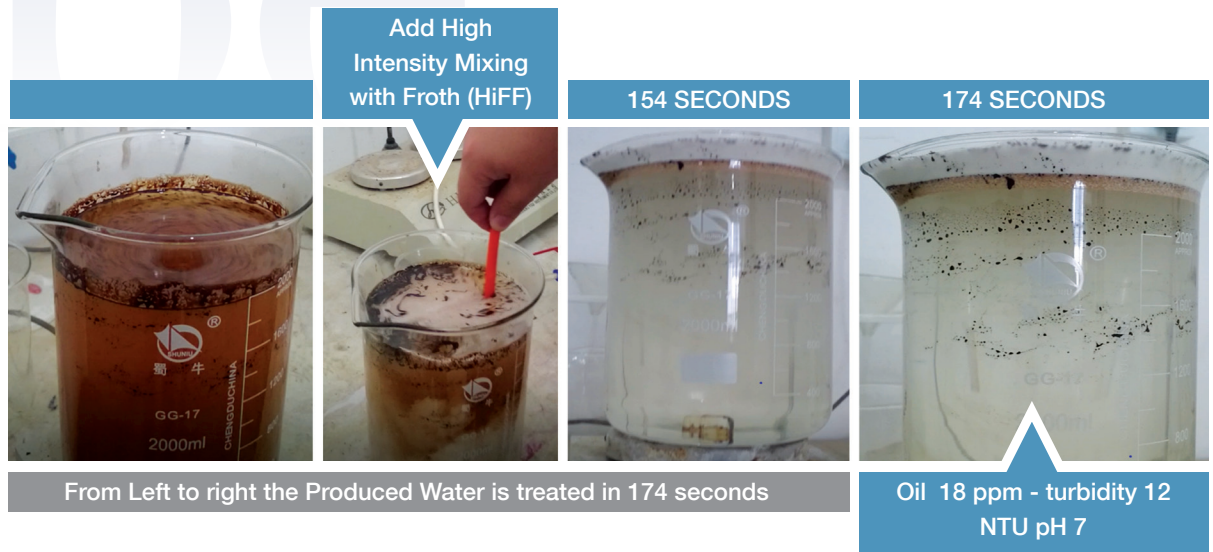
Far Left Photo : RSL (white) powder on the surface of Stainless steel membrane tubeready for filtration.

Right Photo : shows raw water TSS > 500 mg/l ,9 hour filtration.TSS in permeate <2 mg/l, NTU<0.5 and TSS in Membrane Housing was 13000 mg/l at time of backwash.

Bottom Photo : After 6 hrs of filtration, TSS concentrated on upstream side of Membrand to 9500 mg/. Transmembrane pressure 35 kpa.



TYPICAL APPLICATIONS OF HIGH INTENSITY FROTH FLOTATION - HIFF



Treatment of Tailings Pond water from Heavy Oil Production Facility Beaker sample of Nanoflotation Water treatment plant operating 24/7

Left - Highly charged Froth is added-11 seconds • **Middle** - after 46 seconds • **Right** - 116 seconds

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