NANOFLOTATION – NEW WATER TREATMENT TECHNOLOGY FOR PETROLEUM EXPLORATION AND PRODUCTION.

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INTERNATIONAL WATER CONFERENCE

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Canadian Natural

Water use in Energy production

- Oil Sands production-

  2.7 m^3 of fresh water per m^3 of produced oil
- Insitu-Steam Assisted Gravity Drainage (SAGD)

  0.4 m^3 of fresh water per m^3 of produced oil
- Electrical Power generation using coal

  0.68 litres per Kwh
- Electrical Power generation using natural gas

  0.008 to 0.114 litres per Kwh with higher number due to fracing

Water Treatment requirements for Oil and Gas operations

Consistent removal requirements

- Colloidal Solids
- Oil and Grease
- Scaling parameters

Produced Water

Water that results from the extraction of Oil or Gas from the geological formation.

Typically disposed of via a deep well. – back to where it came from

Typically requires the least amount of treatment but if treatment is required it will be for

Colloids and scaling parameters

Tailings pond Water

- In open mining of oil sands , water is used for oil extraction and hydro-transporting of the sand material.
- Water is collected in a tailings pond-approximately 80 to 85% is recycled for the mining operations.
- If RO systems are required for reuse purposes (steam generation or reduction in dissolved metals) then treatment requirements relate to reducing
    - Scaling parameters,
    - colloidal solids and
    - oil and grease

Insitu Oil Sands – SAGD Waters

Water Reuse for this application relates to Steam generation Treatment requirements relate to

- Oil and Grease removal
- Filtration of precipitates due to oxidation of the water
- Silica removal that will cause scaling problems in the steam generation equipment
- IMPORTANT: All of the above have to be treated in a high temperature environment (i.e. 90^0 C)

Frac Flow back water

- Water is used under high pressure with polymers and proppants (sand) to fracture geological formations.
- Approximately 25% of the frac water is recovered with gas extraction over the first 30 days.
- This water needs to be collected and treated for reuse.
- TDS up to 20000 mg/l is OK for reuse water but it is IMPORTANT THAT Scaling parameters be reduced.

As well as

- Oil and grease
- Fe

This also is High Temperature Environment (65^0 C)

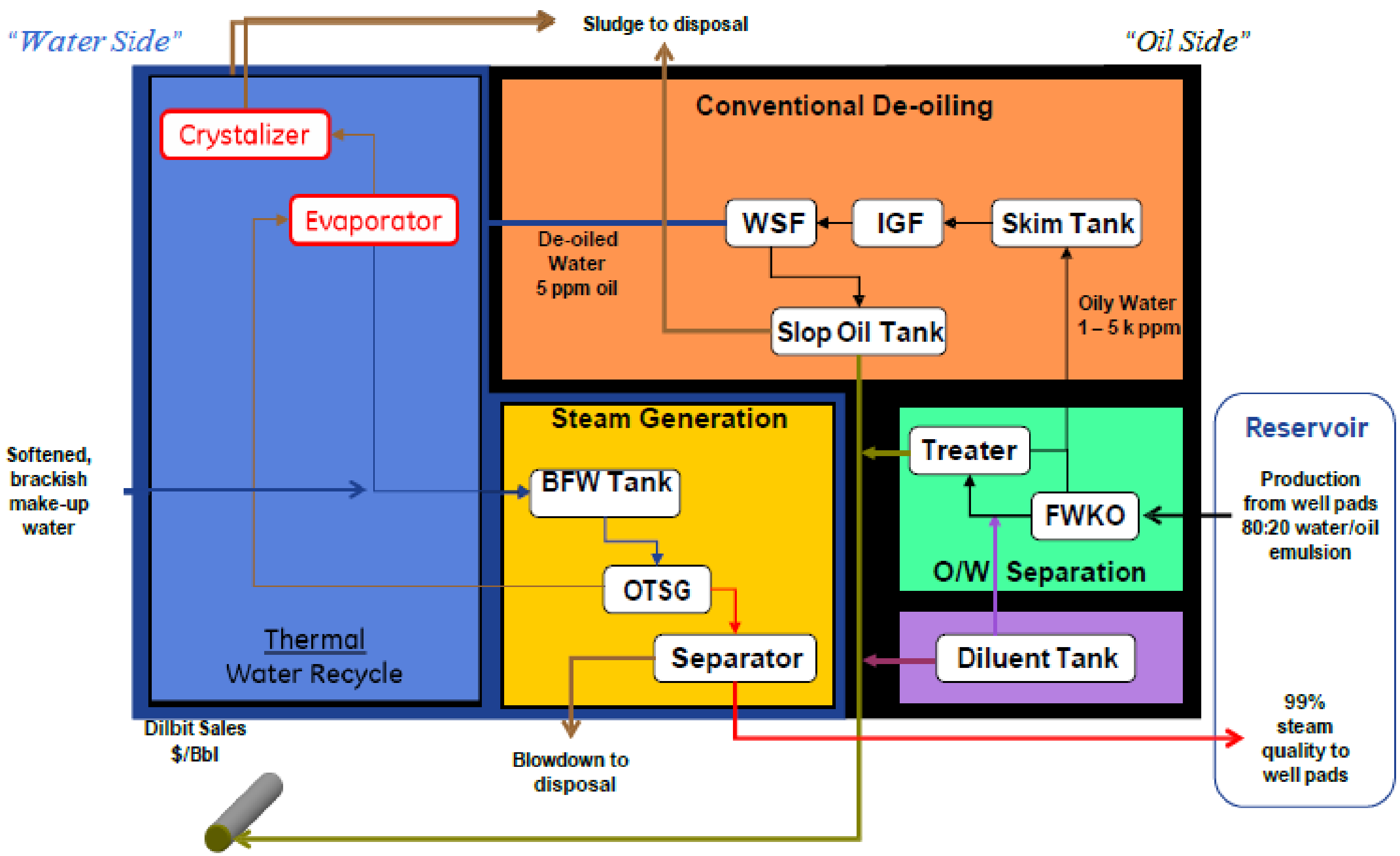
Common treatment concerns

Reduction or removal of

1. Colloidal particles- not just suspended solids
2. Oil and Grease
3. Parameters that cause scaling particularly Barium, Strontium and Silica

In a high temperature and high and low pH operating environment

Common Treatment Methods



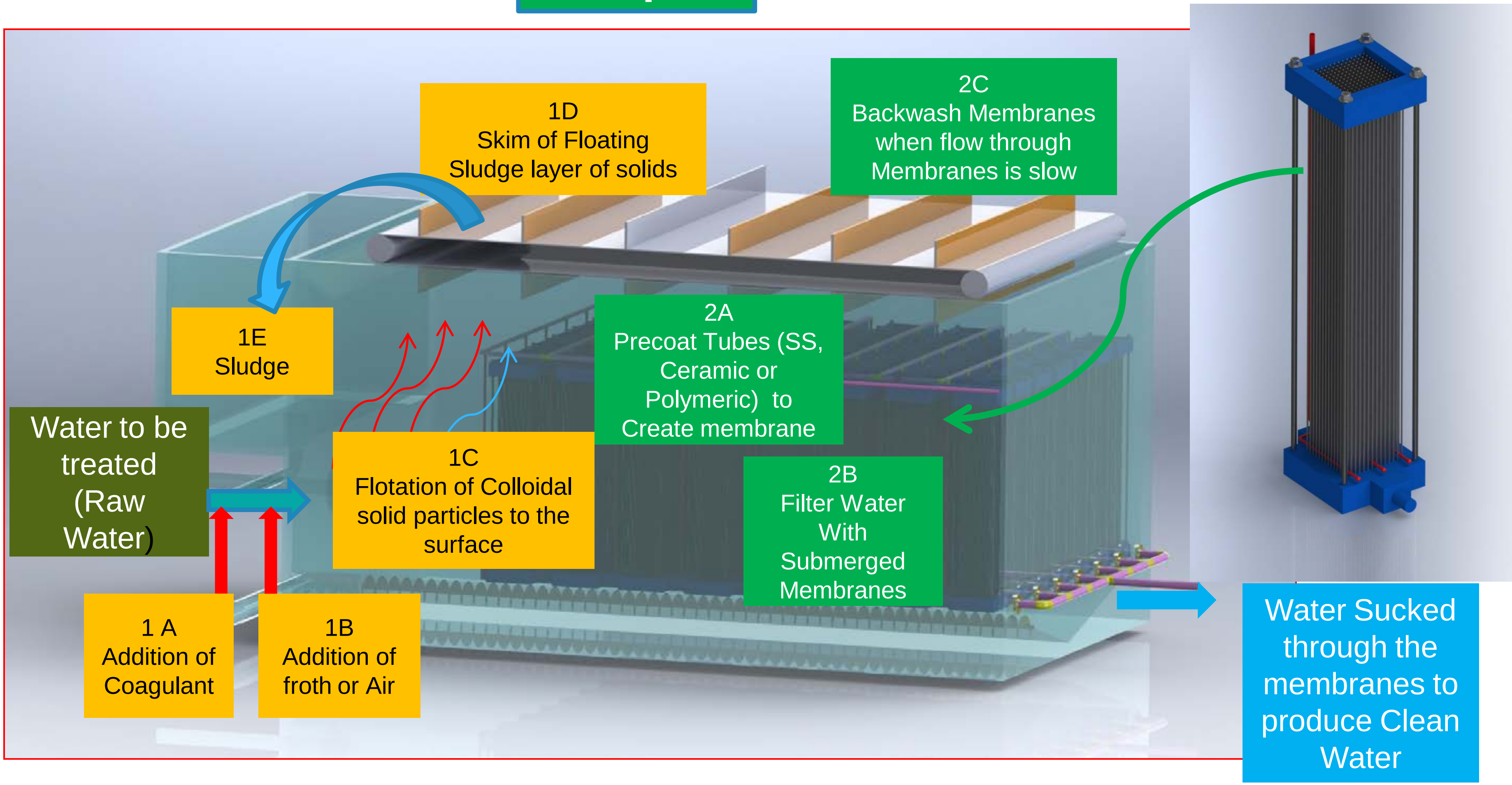
imagination at work

Nanoflotation

What is Nanoflotation?

It is a treatment concept designed specifically to provide the three levels of treatment using a reversed engineering approach where particle attachment to surfaces and scaling is encouraged.

Nanoflotation- Combination of Step 1 **Flotation** technology and Step 2 **Precoated Membranes**

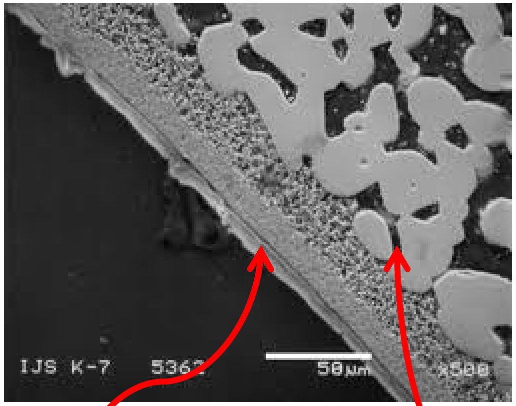


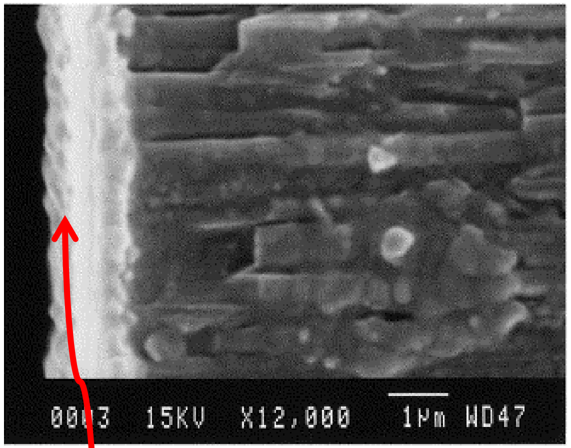
Design Basis – Surface to Surface Attachment

The Four forces for surface to surface attachment

1. The Van der Waal Forces
2. Electrostatic
3. Hydrodynamic
4. Hydrophobic

Membrane layers





Fine Membrane Skin layer (Aluminum, Titanium or Zirconium Oxides) and porous sub layer in ceramic membrane

Fine Membrane Skin layer in Polymeric Membrane

The manufacturing of the membrane skin layer and the attachment of the skin layer is the membranes largest cost factor. Detachment of the skin layer during backwash is a concern

Limited Pressure and Flux (Flow Rate) for membranes

- To reduce fouling the pressure across the membrane (TMP) has to be limited to a maximum of 1 bar.
- For submerged membranes the maximum TMP is 0.7 bar
- Membranes also need to operate at a flux (flow) rate that controls fouling of the membrane. This flux rate is called the "Threshold Flux rate"
- If the flux is above the Threshold Flux rate. **Fouling of the membrane will be very fast**

Cleaning Membranes

Efficiency of the Cleaning Process depends on

1. Chemicals Used
2. Concentration
3. Contact Time
4. Temperature
5. Backwash velocity

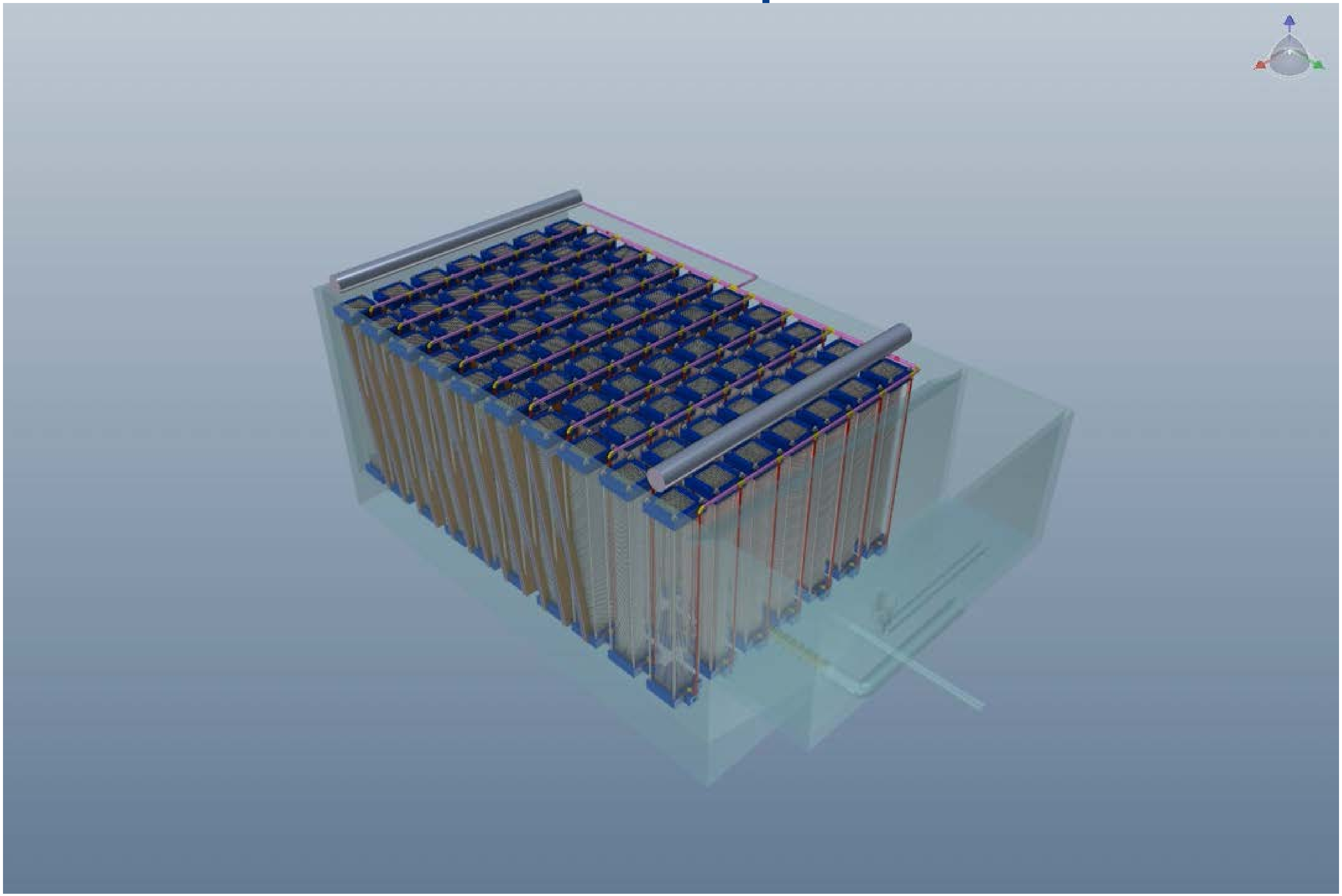
All of this can create complications!

Precoated Membranes-

The Fundamental Difference is the Precoat !!!

- Precoat is used to encourage fouling – surface to surface attachment
- When the precoat is fouled, the precoat is removed by back washing the membrane and is replaced with a new precoat.
- The membrane is not the screen or barrier for filtration. Instead precoat is like a media. Filtration occurs because of the surface to surface attachment using the three forces that typically cause fouling; Van der Waal, Electrostatic and Hydrophobicity.

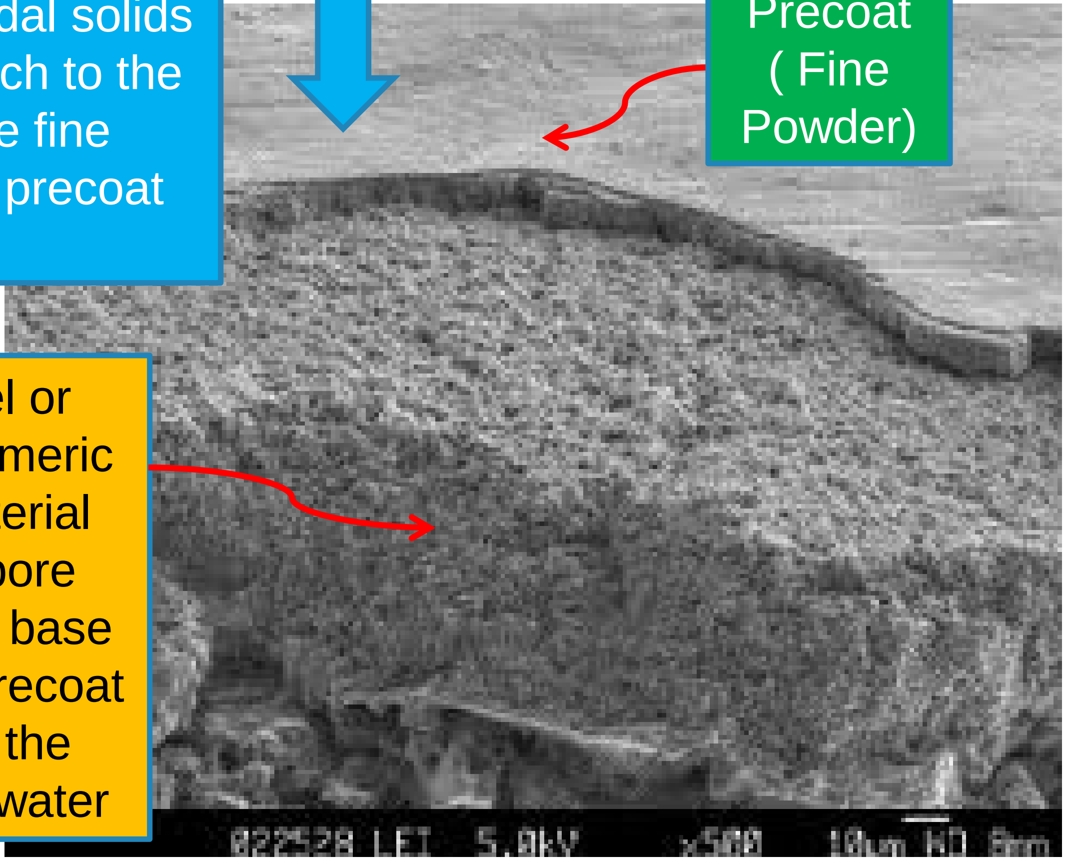
The Precoat process



Typical Precoat Membrane Bundle

Precoat to Create Temporary Membrane Skin Layer. Remove the Precoat layer When it is Fouled

As water passes through the powder precoat media, the colloidal solids in the water attach to the surface of the fine granules in the precoat powder



Precoat (Fine Powder)

Stainless Steel or Ceramic or Polymeric membrane material with 1µ to 5µ pore size. Provides a base for the powder precoat and facilitates the drainage of the water

Treatment results of Pilot test

% reductions

After Flotation

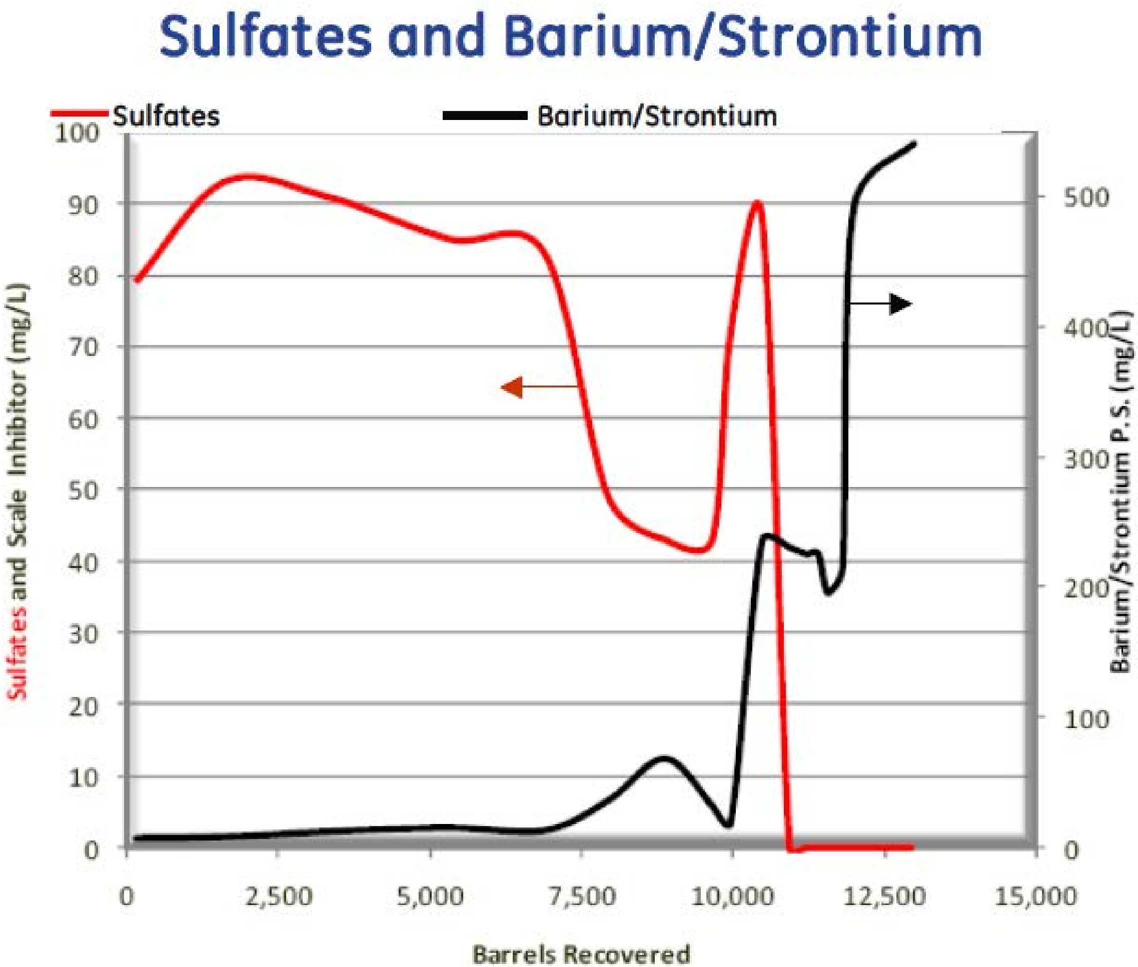
- pH no change
- TSS 90%
- Turbidity 89.2%
- Oil and grease 20%
- Dissolved Silicon 35%
- Aluminum 0%
- Iron 15%
- Barium 33%
- Manganese 35%
- Strontium 7.8%

After precoated membranes

- pH no change
- TSS 100%
- Turbidity 99.9%
- SDI <3 many tests <1
- Oil and grease 20%
- Dissolved Silicon 35%
- Aluminum 71%
- Iron 15%
- Barium 35%
- Manganese 38%
- Strontium 7.8%

Ba/Sr Scaling with Sulfates

Reference: Acharya, Harish R et al , *Cost Effective Recovery of Low TDS Frac Flowback Water for Reuse*, GE Global Research Publication for Department of Energy DE-FE0000784; June 2011



Operating results

- Cycle time : On average, a 60 minute filtration cycle resulted in a 15% reduction in effluent flow rate (40 lpm to 34 lpm) and a 327% increase (0.2 bar to 0.65 bar) in required suction (vacuum).
- Back wash recovery At the end of each filtration cycle, the backwash was fully effective in returning the flow rate and pressure to baseline conditions

Membrane Threshold Flux Rates

Flux rate using a precoat of metal Oxide powder on Stainless Steel Membrane Tubes and water turbidity < 150 NTU in a submerged application with a TMP of approximately 0.5 bar was

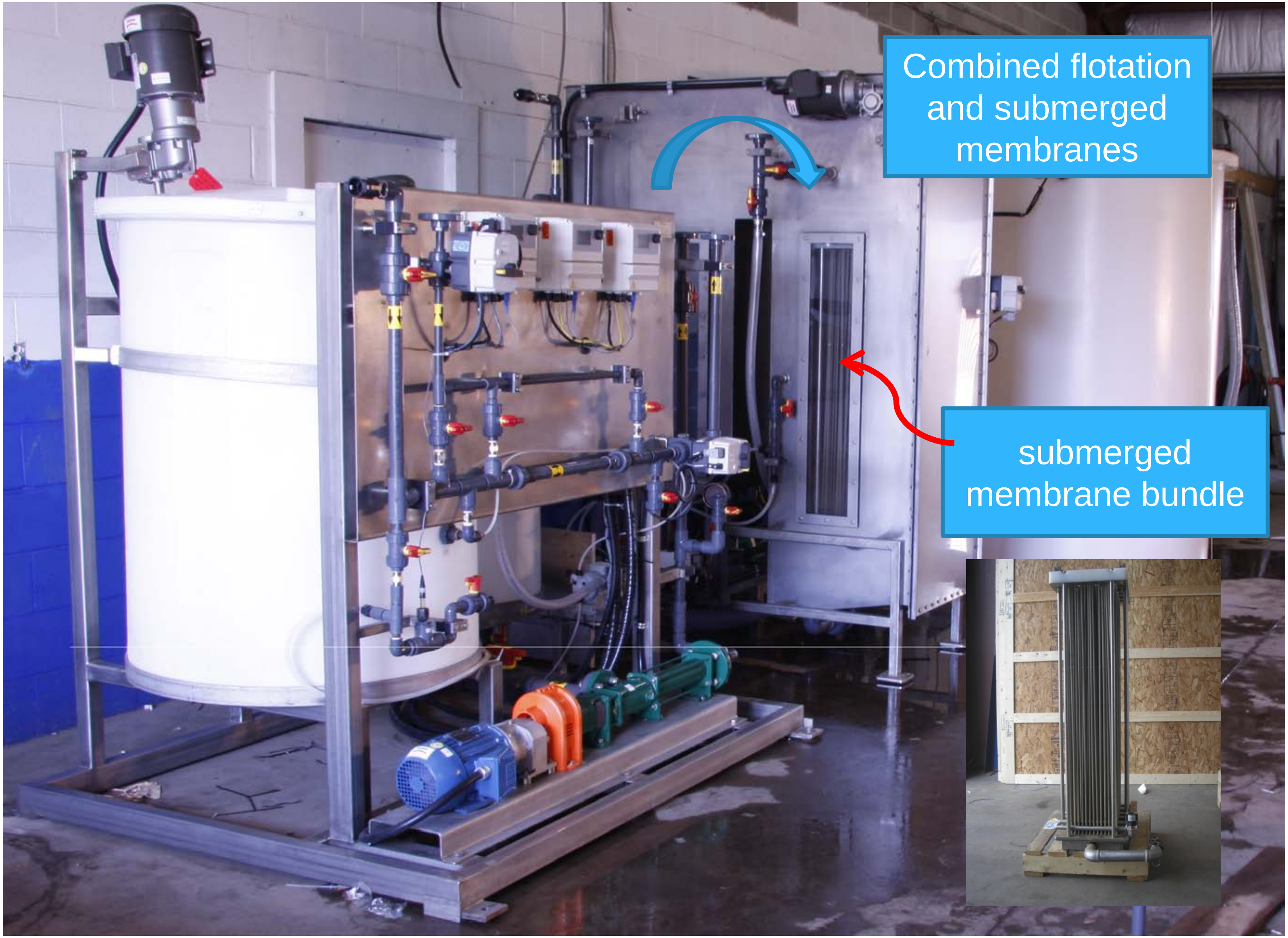
350 to 550 lmh

Approximately 10 to 15 times higher than typical submerged membranes

Energy Utilization

- Typical energy requirements for Microfiltration or Ultrafiltration Polymeric membranes to treat water below 0.3 NTU would require 0.15 to 0.3 kwh /M^3

- Calculated total energy requirements for both components of nanoflotation (Flotation and Precoated membrane) is ***0.08 kwh/M^3 to 0.1 kwh/M^3 …… a 65% reduction***


Combined flotation and submerged membranes
submerged membrane bundle

Conclusions

Membrane Flux Rate	Significant improvement over typical polymeric and ceramic membranes
Energy usage	Low energy requirements for membranes and flotation system- calculated 65%< than typical membranes
Excellent inline mixing with Froth	Results in excellent removals of scaling parameters

Conclusions

Engineered Precoats

- Facilitates reverse engineering approach to encourage fouling (surface to surface attachment) on replaceable precoats

Flexibility

- As Precoats are developed, separation technology will become more effective and selective

Conclusions

Oil and Grease removal

- Reasonably effective in Flotation unit . Better application of Precoats would like improve removal levels.

High Temperature and Corrosive Environment

- With the high flux rates robust membrane materials (SS) can be used with similar overall costs to polymeric

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Thank You

Questions?

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