Treating Produced Water with Ultrafiltration Membranes for Water Reuse

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Global Oil Production vs Produced Water

In the past 20 years:
• Oil production has increased ~25%
• Produced water volumes have almost doubled

• Why?
  • Mainly the aging of conventional wells
  • New techniques
    • Fracking
    • EOR

Source: TUV-NEL
Global Oil Production

2016 Top Oil Producing Nations:
• Russia
• Saudi Arabia
• United States
• Iraq
• Iran
• China
• Canada
• UAE
• Kuwait
• Brazil
Global Water Shortage

2017 Top Oil Producing Nations:
- Russia
- Saudi Arabia
- United States
- Iraq
- Iran
- China
- Canada
- UAE
- Kuwait
- Brazil

Source: International Water Management Institute
Produced Water Reuse Applications

• SAGD / Steam Injection
  • Boiler feed water
• Reinjection into tight formations
  • Requires fine solids removal
• Cooling Tower Make-up
• Irrigation
• Process Water

• All of these applications require a very high quality effluent
• Traditional PW treatment won’t meet these requirements
Typical Produced Water Reuse Applications

**Reinjection**
- Typically 95%-98% removal of suspended solids > 2 microns
- Dependent on reservoir
- Can be reinjected for oilfield production or disposal

**Boiler feedwater**
- Better oil removal increases boiler reliability
- The higher quality of feed water, the more steam is produced

**Irrigation**
- TDS limit (typically requires RO)
- Often O&G, phenol, COD, BOD limits
- Already being applied
Produced Water Reuse Requirements

**Produced Water after Primary Separation**
- TDS >1000 mg/L
- TSS 50-200 mg/L
- O&G >50 mg/L

**RO Feedwater**
- COD < 10 mg/L
- TOC < 3 mg/L
- O&G < 0.1 mg/L
- SDI < 5 – lower the better
- Turbidity < 1 NTU with < 0.5 NTU recommended for long-term, reliable operation
Revive™ Oily Water Membrane System

Siemens ceramic ultrafiltration system for Produced Water Reuse

- Developed during a 5 year R&D Project
- Submerged, Flat Sheet Ceramic Membrane
- Ultrafiltration: 0.10 micron pore size
- Submerged design is different than other options on the market
- We submerge the membranes in a tank and pull a slight vacuum
- Oil is allowed to float to the surface to be skimmed and recovered
Ceramic Membrane Ultrafiltration

What is it?

Revive™ Oily Water Membrane System

• Highly oil tolerant ceramic ultrafiltration membranes
  • Can be placed directly after primary separation

• Can handle very high feed oil concentrations (500-1000 ppm)

• High effluent quality
  • <1 ppm Oil
  • <2 ppm TSS

• Further treated with an RO for:
  • Irrigation
  • High quality water reuse
Membrane Treatment of Produced Water

![Diagram showing the treatment of produced water using primary, secondary, and tertiary methods, with ceramic ultrafiltration highlighted.](image-url)
Conventional Approach to Meeting Strict Effluent Requirement

- Produced Water
- CPI
- Flotation
- Gas
- Oil Reject
- Walnut Shell Filters
- Polishing Filters
- Treated Effluent
Submerged Ultrafiltration Process

Produced Water → CPI → Submerged Ultrafiltration → Recoverable Oil

Gas

Treated Effluent
<table>
<thead>
<tr>
<th>Challenge</th>
<th>Siemens’ solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>High cost</td>
<td>Five year full warranty / price drop of ceramics</td>
</tr>
<tr>
<td>Chemical and temperature limitations</td>
<td>Ceramics are very chemical and pH tolerable</td>
</tr>
<tr>
<td>Produced water variability</td>
<td>Membrane robustness demonstrated through testing</td>
</tr>
<tr>
<td>High oily reject volume</td>
<td>Submerged configuration / Oil is recoverable</td>
</tr>
<tr>
<td>Meeting challenging RO feedwater requirements</td>
<td>Complete particle removal</td>
</tr>
</tbody>
</table>
Ceramic Membrane Performance Study #2—Oil Removals

Heavy crude oil

Feed oil variation to simulate after primary separation

99.9% water recovery—scooped oil off top of tank

4 month test
Ceramic Membrane Performance Study #2—TMP

- Two different heavy crude oils
- No fouling with heavy crude oil
- No chemical cleanings
- Up to 196 LMH flux
Ceramic Membranes for Water Reuse

In House Pilot Testing Has Shown:

- Ceramic Ultrafiltration effluent can be directly reused
  - Effluent Characteristics
    - Oil <1 ppm
    - TSS <2 ppm (non-detect)
    - SDI <5
  - This water can be directly reused
    - Boiler Feed Water
      - OTSG / Drum
      - Reinjected into tight formations
- Can be sent to an RO for further polishing
  - TDS removal for irrigation water
Thank You - Contact

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