

Ceramic Membrane Ultrafiltration Demonstrates Performance for Produced Water Reuse

Siemens Water Solutions
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Topics Addressed in this Presentation



Siemens experience for produced water treatment



Challenges for membranes for produced water



Drivers for ultrafiltration of produced water



Test data

Experience

- 30+ years of produced water treatment experience
- 600+ produced water treatment systems
- 23 countries

Innovation

- 20+ active patents
- 20+ oil/water separation patents
- 10+ pending patents



Typical uses for produced water

SIEMENS

Ingenuity for life



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
- Reduced downtime for cleanings
- Increased production time

Irrigation

- TDS limit (typically requires RO)
- Often O&G, phenol, COD, BOD limits

Membrane Challenges

Challenge Siemens' solution

**High
cost**

**Five year full
membrane warrantee**

**Oil
tolerant**

**Tests with oil concentrations
over 1000 mg/L**

**Produced water
variability**

**Membrane robustness
demonstrated through testing**

**High oily reject
volume**

Submerged configuration

**Chemical and temperature
limitations**

Ceramic membrane

**Meeting challenging RO feedwater
requirements**

Complete particle removal

RO feedwater requirements

COD < 10 mg/L

TOC < 3 mg/L

O&G < 0.1 mg/L

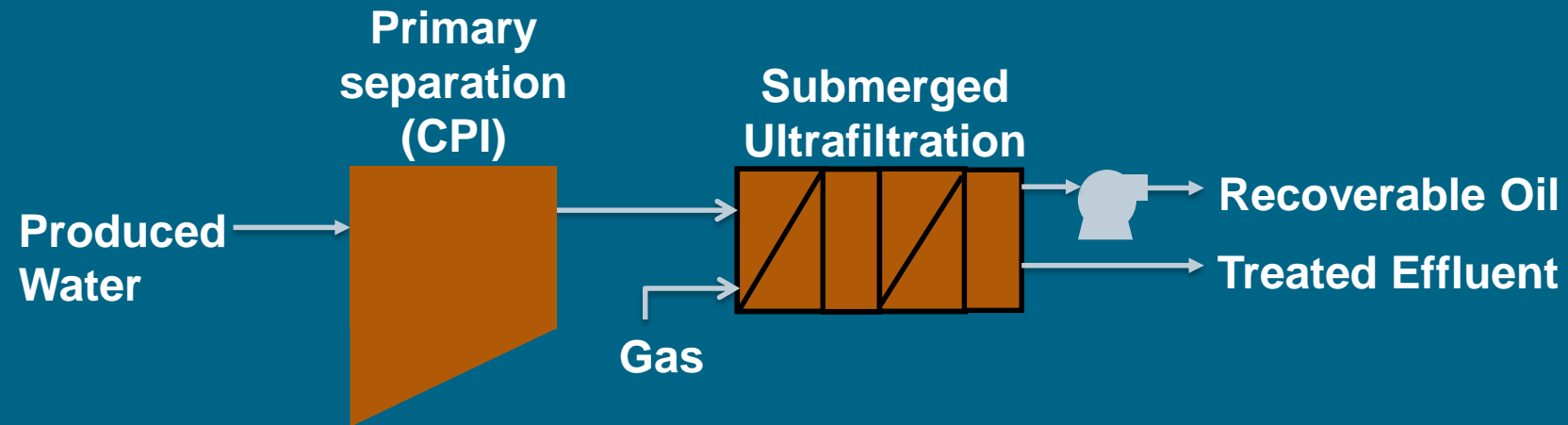
SDI < 5 – lower the better

Turbidity < 1 NTU

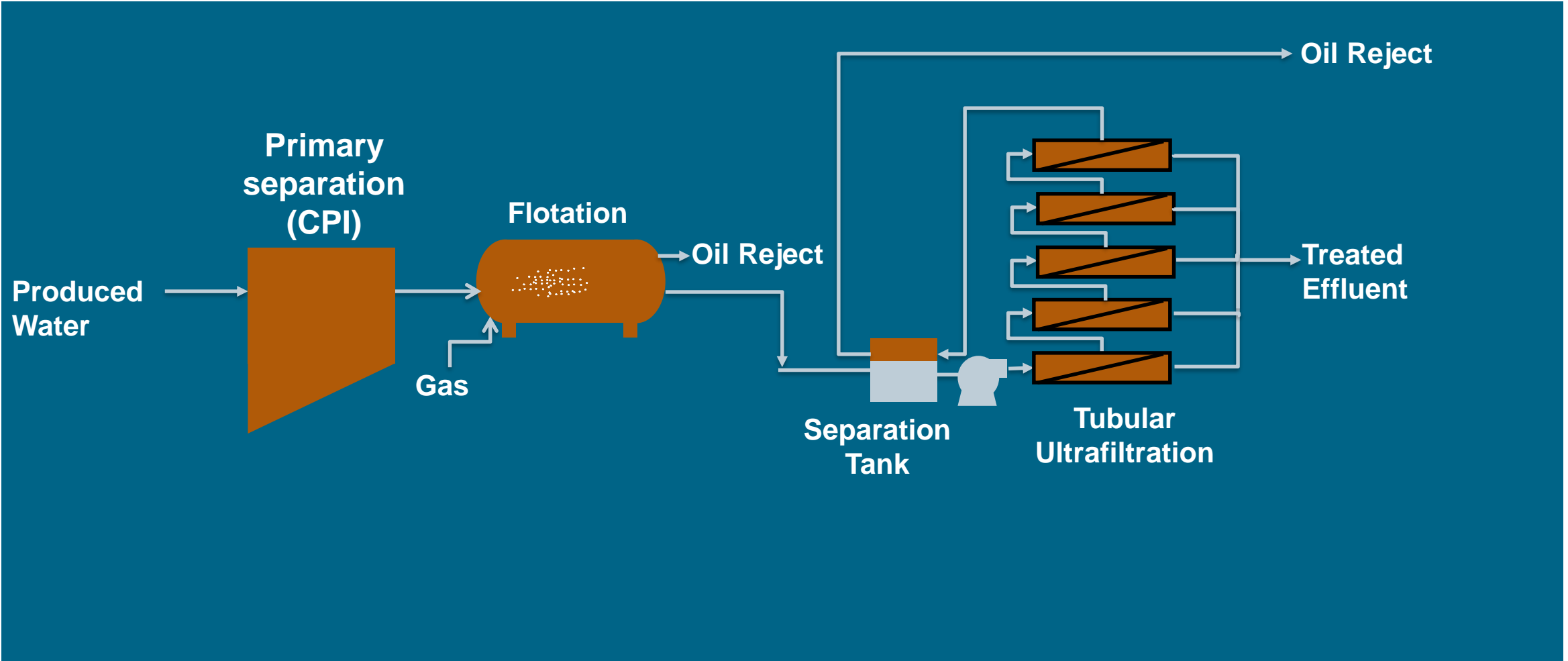
(< 0.5 NTU recommended for long-term, reliable operation)



Submerged Ultrafiltration Process



Tubular Ultrafiltration Process



Submerged vs. Tubular Crossflow Ceramic Membranes

Submerged



>99.9% water recovery



Low pressure operation
(<1 bar)



Only filtrate pumping



High feed oil
(>1000 mg/L)



No oil shearing
(easier oil recovery)

Tubular



80-90% water recovery



High pressure operation
(up to 10 bar)



High feed pumping cost
(recirculation of feed)



Low feed oil
(<200 mg/L)



Oil sheared
(more difficult purge of oil)

Submerged Ultrafiltration Membranes

	Single Stack	Double Stack
Pore size (microns)	0.10	0.10
Surface area per module (m ²)	100	200
Module dimensions WxDxH (m)	2.1 x 0.8 x 1.8	2.1 x 0.8 x 3.3
Module MOC	PVC piping Epoxy potting 304 SS frame	PVC piping Epoxy potting 304 SS frame



Progression of Crude Oils Tested



Initial
evaluation

22 days with
refined oil (API 29)

Long term
test

- 35 days with refined oil (API 32)
- 70 days with Canadian heavy crude oil (API 11)

Validation
with
industry
partner

- 30 days with California heavy crude oil (API 14)
- 81 days with Colombian heavy crude oil (API 11)
- Ongoing with TX crude oil (API 34)

Test Objectives

Filtrate with <1 mg/L solids and oil

High permeability

Membrane robustness

High water recovery

Hot temperature operation

Ceramic Membrane Performance Study—Oil Removals

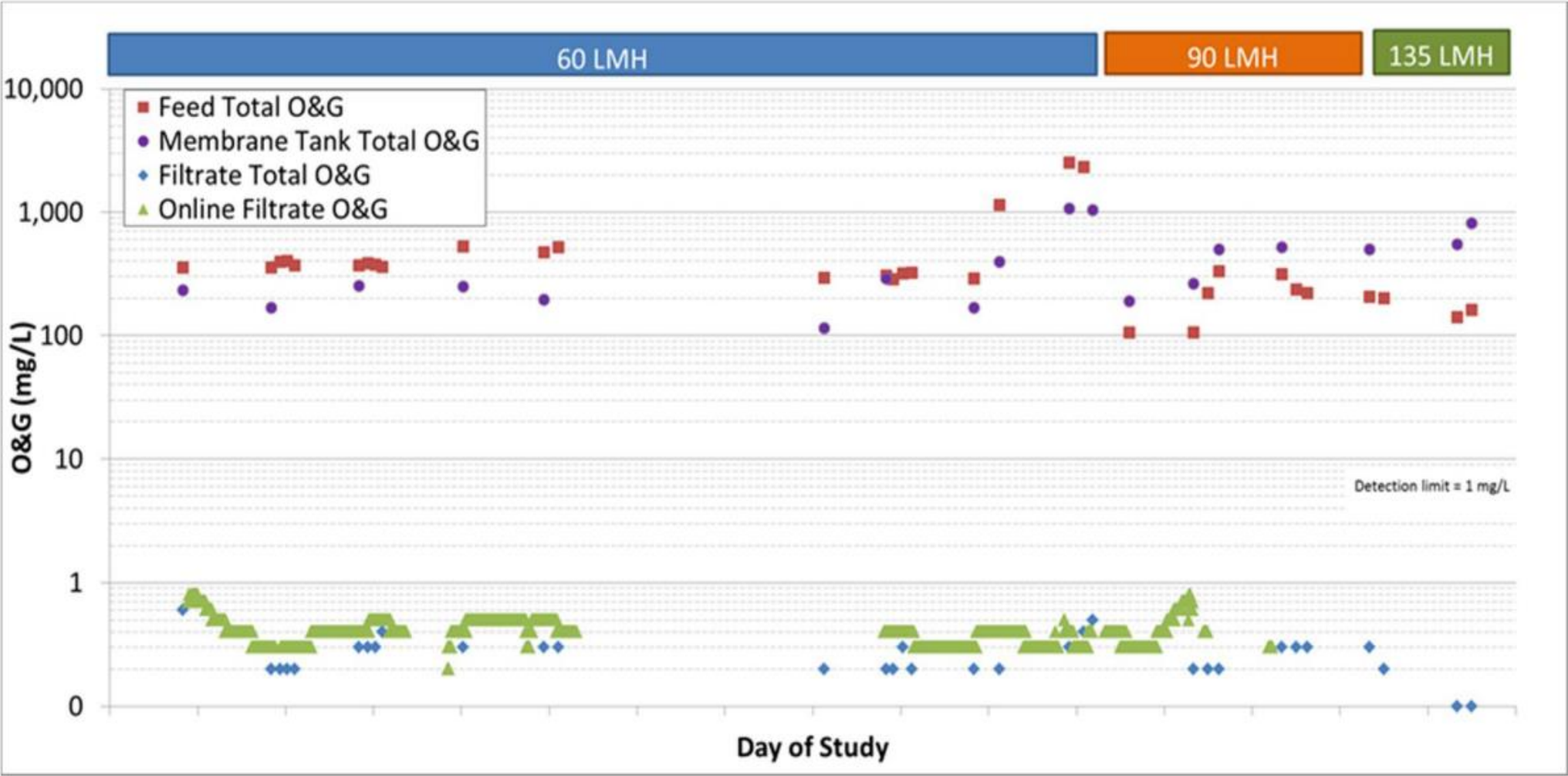


California heavy crude oil (API = 14)

Feed oil variation to simulate after primary separation

99.9% water recovery – daily scooped oil off top of tank

30 day test



Ceramic Membrane Performance Study—TMP

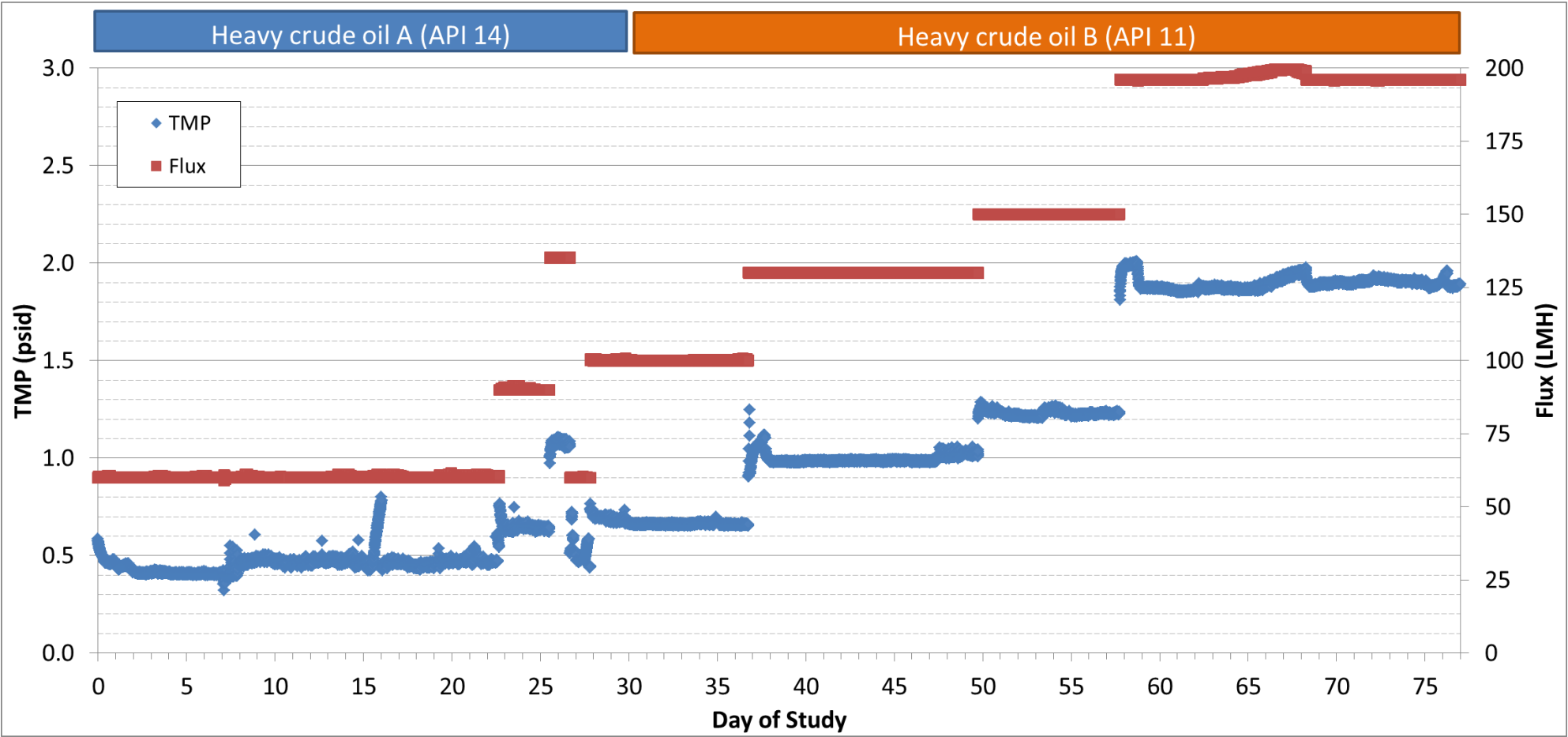


Two different heavy crude oils

No fouling with heavy crude oil

No chemical cleanings

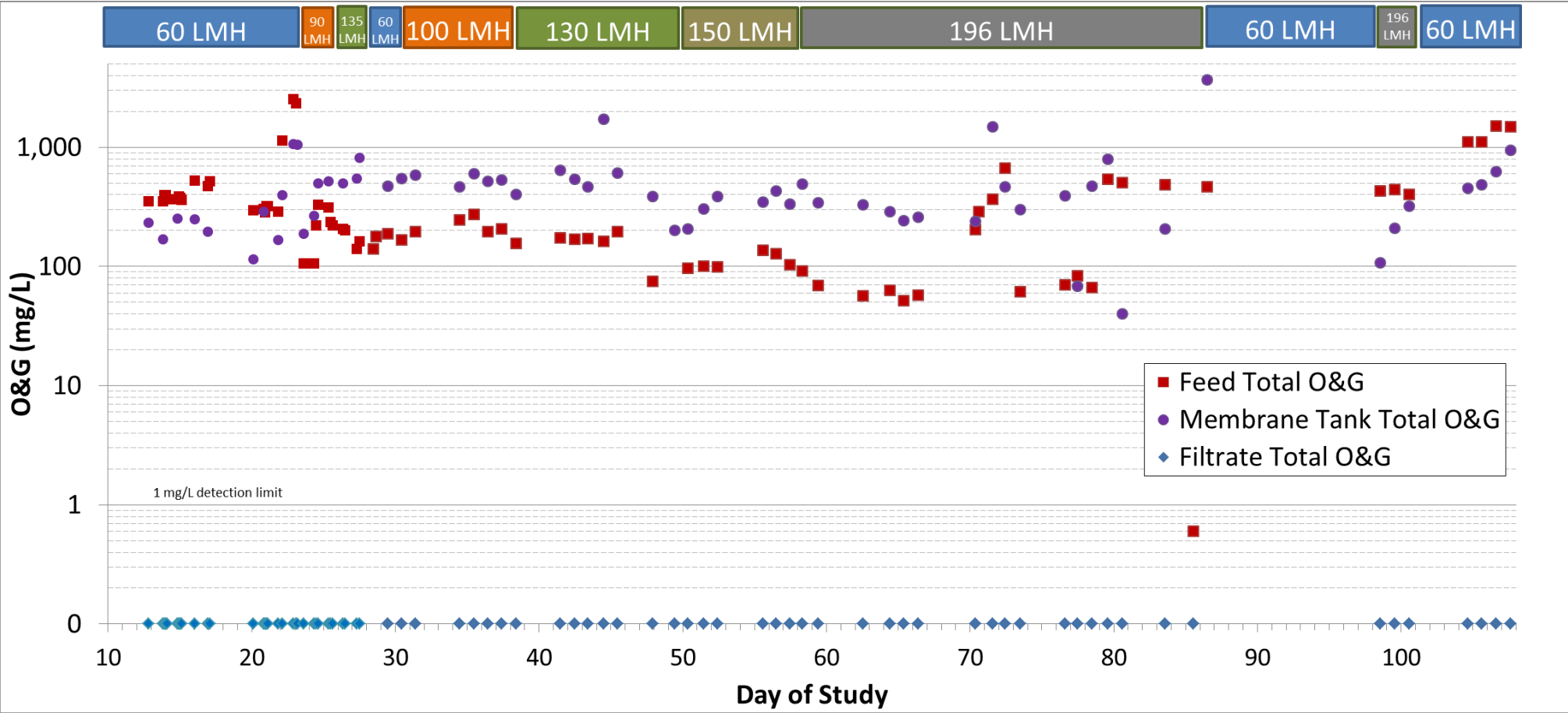
Up to 196 LMH flux



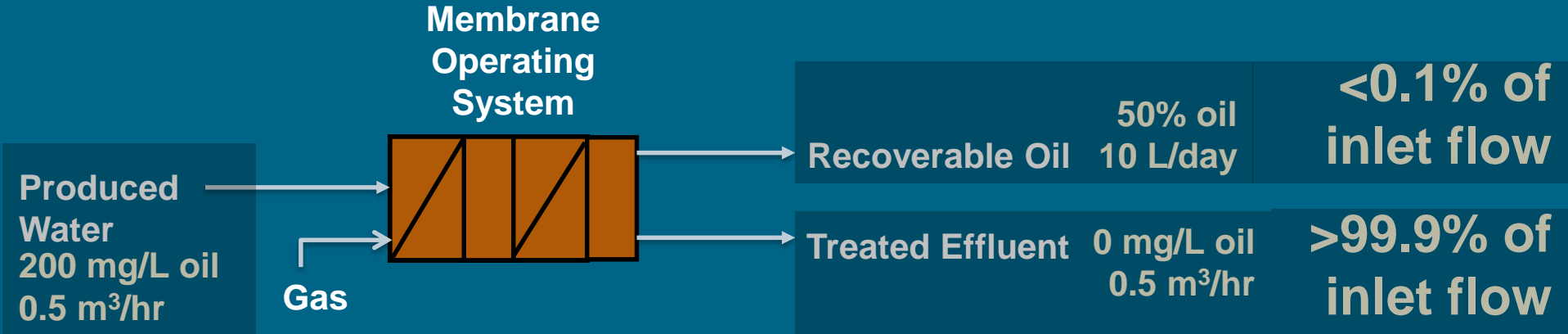
Ceramic Membrane Performance Study—Oil Removals



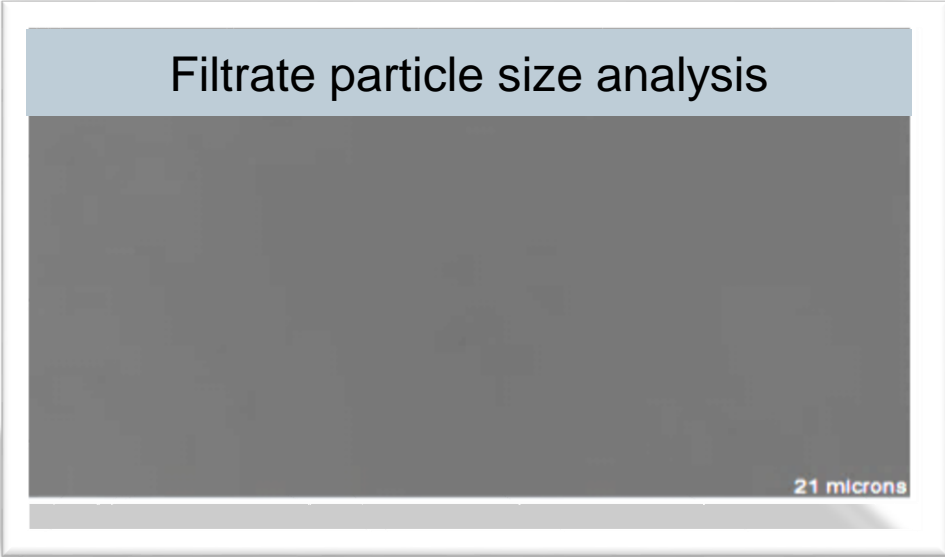
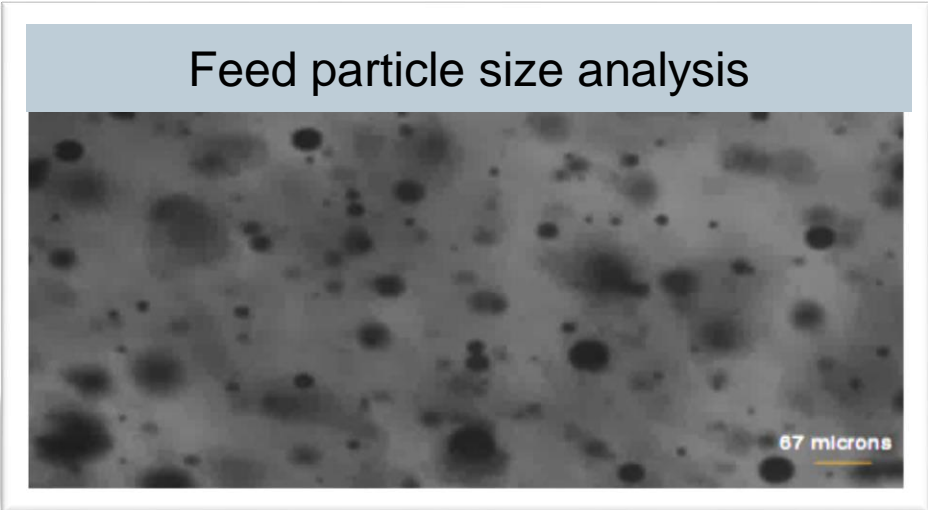
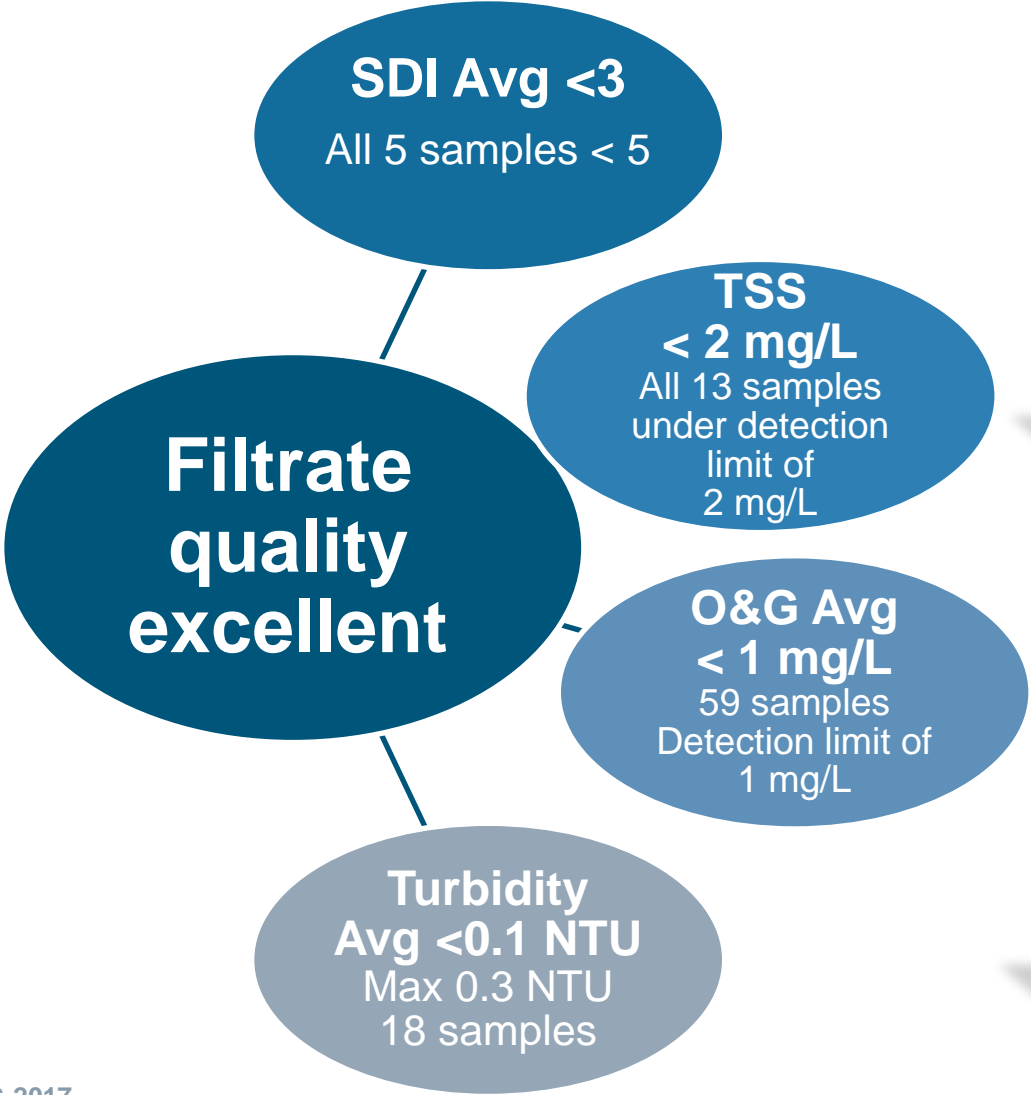
- Heavy crude oil (as noted previously)
- Feed oil variation to simulate after primary separation
- 99.9% water recovery – scooped oil off top of tank
- 4 month test



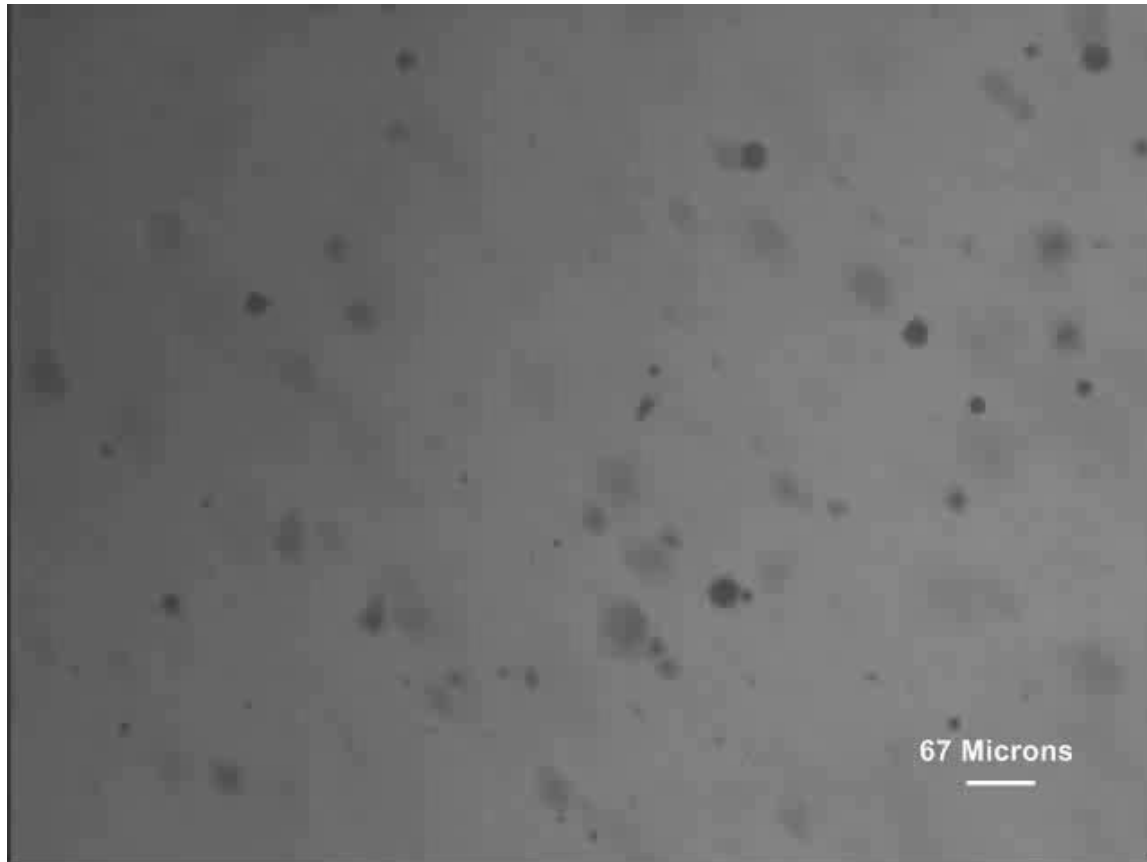
Submerged Ultrafiltration Process – Pilot Mass Balance



Ceramic Membrane Performance Study



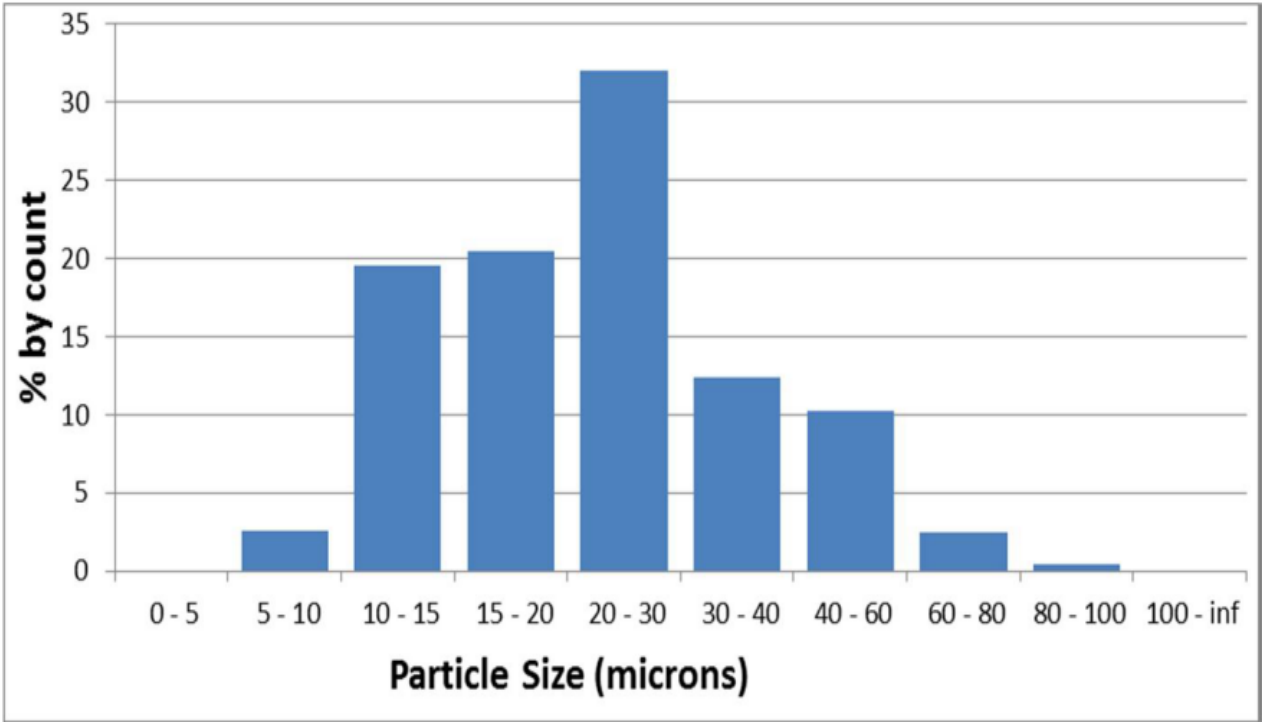
Canty Particle Videos



Ceramic Membrane Performance Study—Particle Size Distribution



- In-line Cauty particle size analysis



Submerged Ultrafiltration Pilot Performance



Feed oil concentration > 200 mg/L



**Permeability 700-1000
LMH/bar despite no cleanings**



>99.9% water recovery



Filtrate TSS < 2 mg/L



Filtrate oil < 1 mg/L

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Produced water fate

