New Technology Application

Cost Reduction while Increasing Operational Efficiency
The Double-Edged Sword of Technology

The New Oil Equation
The surge in U.S. shale production is driving growth in global output.

U.S. oil production
10 million barrels

Change in oil production
10%

World minus U.S.

Accelerating U.S. Oil Production Is a Key Cause of Declining Oil Prices
Millions of Barrels Per Day

Drillers Answer Low Oil Prices With Cost-Saving Innovations

Petroleum: Shale Production vs. Rig Count

Source: CLSA, Energy Information Administration, Organization of the Petroleum Exporting Countries, U.S. Global Investors
Cost Saving Innovations

More Efficient Operations
- Get more out of existing assets
- Optimize exiting production
- Recover more oil

Sustainable Cost Reductions
- Technology innovations
- Reduce capital project costs
- Reduce operating costs

Tanks
Compact Separation

Gravity Base
Density, Gravity & Time

Cyclonic Base
Density & G-force
Technology Application - Onshore Facilities
Cost Saving Opportunities

Special Separation Solutions

- **New Facilities**
  - **CAPEX reduction**
  - **Separation challenges**

- **Debottlenecking Existing Infrastructure**
  - **Increased production or new well tie-ins**
  - **Gain in incremental revenue with residual oil recovery**
  - **Special solutions**
  - **Retrofit applications**
  - **Heavy oil**
  - **Chemical EOR**
  - **Downhole separation**

- **Water Reuse**
  - **Produced Water**
  - **Flowback Water**
Compact cyclonic separation

Conventional vessel separation

- Stokes

\[ v_s = \frac{d_s^2 |\rho_c - \rho_d| \ast g}{18 \mu_d} \]

- Swirling flow \(\Rightarrow\) enhanced gravity

\[ G = \frac{a}{g} \]
Flowback and Production Sands

1. Sand production
   - Flow line clogging
   - Erosion of production choke and upstream facilities
   - Accumulation in separator vessels
   - Continuous monitoring and safety supervision
   - Intervention & maintenance

Cyclonic Separation

Goal - Achieve earlier production
Cyclonic Sand Separation – Wellhead Desander

Conventional Sand-trap

Gravity base

Cyclonic Sand Separation

Inlet

Inlet

Single/Multi phase flow + sand

Liquid outlet

Concentrated slurry, to accumulation vessel

Cyclonic technology proven and applied in the most demanding environments

Inlet

$F_d$

$F_g$
Wellhead Desander

Application at unconventional shale
✓ Drill-out, Flowback & Production operations
✓ >95% Sand removal
✓ Compare conventional with cyclonic separation
✓ Controlled test criteria
✓ Measure/Sample solids

Sand volume/mass measurement
Operator’s benefit

- Avoids costly repairs & throwaways to downstream equipment due to erosion
- Eliminates solids carryover in water & oil streams after separator
- Accelerates the move to a Productions stage
- Avoids operational slowdowns and increases safety
Wellhead Desander Performance – Permian
Lea County, Permian TX

- Desander unit is connected directly to the wellhead - sole sand separation unit
- Samples are constantly taken every hour, at upstream and downstream locations of the unit to monitor its performance

Sand concentration profile:
- Sand concentration from the wellhead varied from trace to over 1.5% (v/v)
- Desander outlet was continuously recorded as trace

Separation Efficiency >99%
Wellhead Desander Performance
Before and after Desander application

Prior to Desander Application
- Two Santraps were used (10k and 5k)
- Replacing plug and seats every 3 to 4hrs
- Separator sand dumping – Every 30 minutes

Post Desander Application
- No Sandtraps used in front of Desander
- Desander is the Single sand separating device
- After 14Hrs, only ONE plug and seat replaced
- Only partial erosion
Current practice of using two Sand-Traps per operation

Cost savings show, removal of one Sand-Trap and use of the Desander along with the eliminated costs it brings by efficient separation

Single well, Desanding related, approximately 10 days in durations
Wellhead Desander Performance – Eagleford
Gonzales County, Case History - II

Sand Separation Efficiency >99%
2 Bulk Oil Water Separation

InLine Liquid-Liquid Separation

- Removes oil from water
- Compact and Mobile – “Facility on a Skid”
- High separation efficiency, >90% reduction in the hydrocarbon content
- Proven cyclonic technology powered by the operating flow (<50 PSI)
- Small footprint, easy to install; once setup, it operates with minimal maintenance
Production DeWaterer – Applications

- **Inlet**: A single phase flow
- **Outlet**: A separated flow of water and oil

**Production – Recover More Oil**

- Current: Water with 500-2000 ppm O&G
- Future: Water with >200 ppm O&G

**SWD – Facility on a SKID**

- SWD Well
- SWD Disposal Pad
- Heater Treater
- Separator
- Well pad
- Oil

**SWD – Accommodate More Water**

- **Option 1**: Inline DeWaterer
- **Option 2**: In-line DeWaterer
Production Facility - EOR

Case History - Central Texas, 110Kbbls/day

Annual Savings $2.4M
Production/Disposal Facility Pilot

Case History – Delaware Permian Basin, 4Kbbls/day

![Diagram of production/disposal facility](image1)

![Bar chart showing Oil & Grease levels](image2)

![Photos of the facility](image3)

9/10/2015
## Cost Savings - Dewaterer

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Gun Barrel Inlet</th>
<th>Gun Barrel Outlet</th>
<th>After Filter Pods</th>
<th>Dewaterer Water Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Concentration (ppm)</td>
<td>775</td>
<td>580</td>
<td>455</td>
<td>120 ppm</td>
</tr>
<tr>
<td>Dewaterer Performance Improvement (%)</td>
<td>84.5</td>
<td>79.3</td>
<td>73.6</td>
<td></td>
</tr>
<tr>
<td>Incremental Oil Recovery (bbls/day)</td>
<td>32.7</td>
<td>29.0</td>
<td>22.8</td>
<td></td>
</tr>
<tr>
<td>Incremental Revenue (USD/day)</td>
<td>$1,800.8</td>
<td>$1,595.0</td>
<td>$1,251.3</td>
<td></td>
</tr>
<tr>
<td>Incremental Revenue (USD/Year)</td>
<td>$657,273.8</td>
<td>$582,175.0</td>
<td>$456,706.3</td>
<td></td>
</tr>
</tbody>
</table>

*50K bbls/day Facility & $55/bbl Oil Price

### Advantages

- Higher oil recovery
- Compact Capex and Opex Savings
- No Moving Parts
- No Solids Accumulation
- Maintenance Free
Produced and Flowback Water Reuse

Understanding the water lifecycle economics and the end use is critical to technology selection.
Oil and Grease
Effect on Bacteria

- Recover residual oil
- Compact mechanical separation
- Significant reduction in Bacteria
- Cost savings on Biocide
- Reduced load on subsequent unit processes

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Raw Water</th>
<th>Treated Water</th>
<th>Recovery / Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil &amp; Grease (ppm)</td>
<td>287</td>
<td>51</td>
<td>82</td>
</tr>
<tr>
<td>Bacteria (ME/ml)</td>
<td>$9.5 \times 10^7$</td>
<td>$1.6 \times 10^7$</td>
<td>83</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>1.61</td>
<td>1.57</td>
<td>3</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>51</td>
<td>49</td>
<td>4</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>381</td>
<td>378</td>
<td>1</td>
</tr>
</tbody>
</table>
Total Suspended Solids

- Solids in oilfield water:
  - Suspended Solids
  - Sand, Silt, Clays, Humic Acid, Fulvic Acid, Microorganisms
  - Colloidal Particles
  - Microorganism, Sand, Clays
  - Dissolved Substances
  - Cations, Anions, Organic Matter, Gases

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1/3 Pore Throat</td>
<td>Bridge Instantly</td>
</tr>
<tr>
<td>1/3 to 1/7 Pore Throat</td>
<td>Deeper Invasion</td>
</tr>
<tr>
<td>&lt;1/7 Pore Throat</td>
<td>Non-Damaging</td>
</tr>
</tbody>
</table>

Courtesy: www.bakerhughes.com
Total Suspended Solids

Inline Compact Desilting Technologies

> 95% Solid removal (>10 Microns size)

Cyclonic for Solids Removal

- Inlet:
  - Single phase + sand
  - Multi phase + sand
- Sand outlet:
  - Concentrated slurry
  - Sand accumulation vessel

Inline Compact Desilting Technologies

> 95% Solid removal (>10 Microns size)
Boron – A Critical Component

- Boron in produced water
- Concentration Range
  - 10-200mg/ltr
- Difficult to remove

**Why Cross-Link?**
- Low cost
- Ease of use
- High viscosity
- Fluid recovery

**Why Treat**
- Interference with CXL
- Premature viscosity
- Fluid Degradation

---

**Paradigm Shift**

<table>
<thead>
<tr>
<th>Boron Levels</th>
<th>2010</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>60</td>
</tr>
</tbody>
</table>

---

**Frac Fluid Stability**

A

B

- Boron in produced water
- Concentration Range
  - 10-200mg/ltr
- Difficult to remove
Boron – A Critical Component

Boron Removal ~ 99%

Removal of special constituents

Stages in the water treatment process
High Efficiency: NF and RO

Polyamide Thin Film Composite

Water passes through

FLUX: Flowrate per Unit Membrane Area

RECOVERY: Ratio of Product to Feed Flowrate

- Increased Flowrate: 3X higher per unit membrane area due to coating
- Increased Recovery: 7X less wastewater to truck
- Reduced Cleaning Time: 1 hour coated vs 3-4 hours uncoated

Membranes from different manufacturers showing flux vs. rejection trends of current technology

DOW membrane 90% market share of seawater desulfation units

Teledyne-FMC membrane 33% higher flux & 50% lower sulfate in permeate than DOW membrane

US Army unit: 2000 lbs, 4 hrs to assemble in 4 skids, 20 GFD, 3-6 hrs to clean

Teledyne unit: 385 lbs, push button operation, 60 GFD, 1 hr. to clean

Advantages of membrane coating
- 5X smaller system size
- 5X lower weight
- 3X more flowrate
Conclusion

- New technology: Adapting will only make them more efficient and dynamic
- Near-term impact – Low hanging fruit
  – Immediate impact on CAPEX/OPEX
- Innovation in the sector is increasing
- Risk Averse
- Few early adaptors
Thanks