Treatment Options for Recycling Produced Water

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July 9, 2013
Unconventional Oil & Gas Water Management Forum
Grapevine, TX
Considerations

- Drilling and Completion Program
  - *Exploratory*
  - *Development*

- Infrastructure
  - Frac pits *(Fresh Water)*
  - Recycle pits *(Produced Water)*
  - Storage for processed water
  - Transfer lines

- Storage capacity
  - Untreated
  - Processed

- Frac Fluid Chemistry
  - Slick water
  - Fresh linear or cross linked gel
  - High salt tolerant gel
Recycling Challenges

- Fresh water
  - Few problems with frac fluid chemistry

- Produced or Saline water
  - Must be cost neutral with fresh water
  - Minerals can interfere with frac gel
  - Water quality varies widely
  - May cause scale or bacteria growth

- Study needed determine water quality targets
  - Results specific to a basin or formation
  - Results will point to type of water treatment needed

- Regulations
  - Recycle or produced water pits often have to be permitted
  - OK and TX require design, certification, and construction supervision by a professional engineer
Concerns with Produced Water Reuse

Formation Damage
- Potential for solids to compromise fracture geometry
  - Improper fracture propagation
  - Potential for reduction in production
- Suspended colloids not removed by simple filtration

Scaling
- Increased potential with higher hardness
- Theoretical calculations and experiments required

Fluid Formulation
- Varied water quality
- Polymer hydration issues in high salinity water
  - Greater issue with polymer crosslinking
  - Premature crosslinking due to boron

Source: Halliburton
What Are Your Choices for Water Treatment?

- Evaluated more than 40 companies
- More getting into our business every day
- A large number of technology choices and many variants of those technologies
- Overview of some of the available technologies
- Discuss some specific examples
Treatment Options

There are a number of treatment options available to producers, with options including dilution, settling, chemical treatment, filtration, clarification, electro-coagulation, and distillation.

- **Dilution**
  - ~$1.50 - $2.00/bbl
  - Involves blending flowback or produced water with freshwater during fracturing.
  - Not free - has a handling cost for frac tanks, containment, water transfer, etc.

- **Settling**
  - ~$2.00 - $2.50/bbl
  - Must allow enough residence time in flow back pits or frac tanks for solids to settle.
  - Risks associated with storing raw water on location for long periods of time.

- **Filtration**
  - ~$2.00 - $3.00/bbl
  - Bag filters, disk filters, or sand filters can be used. Other types available.
  - Issues can arise from expended filter sock disposal and bacteria introduction.
  - Water sources for back flushing system can be logistically difficult.

- **Chemical Precipitation**
  - ~$2.50 - $4.00/bbl
  - Involves pH adjustment and the addition of polymers or other floculants.
  - Issues can arise from excess sludge formation and sludge disposal.
  - Chemical drum or tote management can be logistically difficult on location.

- **Clarification**
  - ~$3.50 - $4.50/bbl
  - Involves the use of equipment including DAFs or clarifiers.
  - Typically involves chemical precipitation in conjunction with clarification equipment.
  - Advantages include few moving parts and less downtime.

- **Electro-Coagulation**
  - ~$4.50 - $5.50/bbl
  - Sacrificial plates create a hydrolyzed metal sweet floculant that significantly lowers total suspended solids (TSS), greases and oil, and in some cases metals count.
  - High operating costs relative to other TSS treatment systems.

- **Distillation**
  - ~$5.50 - $8.00/bbl
  - Highest effluent water quality.
  - Effluent can potentially be placed in freshwater impoundments with approved NPDES permits.
  - Highest operating costs due to energy requirements.
Technology TDS Ranges

- **High**
  - Crystallizers
  - Brine Concentrators
  - Brackish RO
  - IX
  - RO

- **Med**
  - Chemical Precipitation

- **Low**
  - Electrocoagulation
  - Filtration/Hydro cyclones

Source: Halliburton
Water Treatment Comparison

- **EC**
- **Distillation**
- **Evaporation**
- **Ozone**
- **Ultrafiltration**
- **RO**
- **Chemical Precipitation**
- **Filtration Hydro cyclone**

**Water Value Added**
- High
- Med
- Low

**Treatment Cost $/ BBL**
- 0
- 2
- 4
- 6
- 8

- TDS removal NOT necessary for most water reuse
- Small percentage removal of TSS/HC passing on residuals

Source: Halliburton
Centralized Facility

- Fresh water supply
- Fresh water storage
- Water treating equipment
- Influent/ Effluent storage
- Class II UWD well
Water Treatment and Reuse
Dilution and Settling

- Need large lined permitted pits
- Simple removal of TSS
- 100% water recovered for reuse
- Can use with all produced waters
- Low energy consumption
- For settling need sufficient residence time
- Blend fresh water with produced water
- Not free
Filtration

- Simple removal of TSS, using filter cartridges/socks/media
- 99.9% water recovered for reuse
- Inexpensive with all waters
- Low energy consumption
- Have filtered at 100 bbls per minute
- Highly mobile
- Must properly dispose of filters or filter media
- Need fresh water for back flushing
Chemical Precipitation/Clarification

- Chemical removal of TSS and organics
- Adjust chemical protocol to meet required water specifications
- Sludge can be dewatered and disposed of in landfills

Typical DAF System

Fig. 1. Schematic of dissolved air flotation
Induced Gas Flotation Separator (Clarification)

Single Cell IGF - Water Clarification: Level I Treatment

- Technology refined over decades
- Low and Efficient residence time
- Minimal Maintenance and Operator required – Few Moving Parts
- TSS and floatable hydrocarbon output < 10 ppm
- Easily Scalable from 2,500 bpd and up – Small Footprint
- Recycles low TDS water for beneficial reuse as a Stand Alone Unit
Electro Coagulation

- Removes suspended solids and heavy metals
- Treats water with TDS ranging from 100 – 300,000 mg/L
- Coagulates particles < 1 micron
- Reduces turbidity to < 10 NTU
- Breaks emulsions
- Fully automated
- Scalable
- Self-cleaning
Mobile Distillation

- Removes suspended solids and heavy metals
- Treats water with TDS ranging from 100 – 300,000 mg/L
- Coagulates particles < 1 micron
- Reduces turbidity to < 10 NTU
- Non-polymer based water treatment contributes up to 75% reduction in sludge generation
- Breaks emulsions
- Fully automated
- Scalable
- Self-cleaning
Mobile Distillation (Vapor Recompression)

- **Rapid deployment**: Smaller footprint, no massive setup
- **Self-contained**: Ready to go, connect and play
- **On-board power** or adaptable to any on-site power source
- **Robust**: Instantly configures to dynamic feed water conditions

- **Low Energy**: 3 phase 480 V - 300 kW power source (AVARA 1000)
- **Wireless uplinked**: remote oversight and control
- **Durable**, Resilient, Reliable – Oil & Gas Field Tough
Distillation

- Highest effluent water quality
- Large capacity operations
- Highest energy requirement
- Highest operating cost
- Can discharge water back into the environment with proper permits
- Energy costs can be mitigated by using waste heat
### Water Quality Limits for Fracturing Fluids

<table>
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<tr>
<th>Parameter</th>
<th>Limit</th>
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<tr>
<td>Bacteria</td>
<td>$&lt; 10^5$/ml</td>
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<tr>
<td>pH</td>
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<tr>
<td>Temperature</td>
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<tr>
<td>Bicarbonateates</td>
<td>$&lt; 300$ ppm</td>
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<td>Calcium and Magnesium</td>
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<td>Sulfates</td>
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<tr>
<td>Boron</td>
<td>$&lt; 10$ ppm</td>
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Ecosphere

- Combination of several processes
  - **Phase 1**
    - Filtration
    - Oxidation using ozone injection and ultrasonic cavitation
    - Coagulate suspended solids
    - UV light for purification
    - Carbon Filtration
  - **Result Clean Brine Water**
  - **Phase 2**
    - One micron Filtration
    - RO to treat water from less than 45,000 ppm TDS to 50 ppm TDS
  - **Result Fresh Water and Concentrated Salt Water**
Rockwater

• Combination of several processes
  • *Phase 1*
    • Filtration
    • Oxidation using Neohydro electro-oxidation equipment
    • Coagulate suspended solids
    • Clarify water
  • *Result Clean Brine Water with 130 ppm Boron*
Express Energy/Omni Water Solutions

• Combination of several processes
  • **Phase 1 (Express)**
    • Gravity separation
    • Chemical injection
    • Coagulate suspended solids
    • Clarify water
  • **Result Clean Brine Water**
  • **Phase 2 (Omni)**
    • Oxidation using Ozone
    • Multiple filtration stages
    • RO to remove Boron
  • **Result Clean Brine with less than 5 ppm Boron**
Why Newfield Recycles Water

- Saving Fresh Water – 10 million barrels per year
- Saving Money – $50 million per year
- Limited supply of fresh water due to drought
- Reduce the need to dispose of produced water
- Potential to reduce transportation costs
- Environmentally responsible
- Improved social license
Goals for Cana Woodford

Minimize Fresh Water Use

Recycle Produced Water For Less Than $2.00

Replace Fresh Water with Saline Water
Questions!!??!!