Key Considerations for Frac Flowback / Produced Water Reuse and Treatment

NYWEA Spring Technical Conference – Syracuse, NY

June 4, 2013
Today’s Agenda

• Overview of Hydraulic Fracturing Process
• Water Quality
• Treatment Alternatives
Hydraulic Fracturing

- Frac Method: Typically slick water frac
- Wells: 4 to 8 wells per pad
- Frac Water Volume: 4 to 6 million gallons per well (95k to 142k bbl)
- Flowback: ~20 – 25% returns within the first 7-14 days
Composition of a Fracturing Fluid

- Fracturing solution consists of sand and water
- Additives include biocides, corrosion inhibitors, O2 scavengers, friction reducers, surfactants, etc.
## Frac Flowback Water Quality

All values in mg/L

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Wide Variation in Frac Flowback Chemistry

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All values in mg/L
Typical Flowback Characteristics

The longer Frac water is in the formation, the higher the TDS levels may become.

Source: Siemens AG 2009
Total Dissolved Solids from the Produced Water Database in the United States

• Typical Produced Water TDS Levels – Selected Areas
  - Powder River CBM – 1,200 mg/l
  - San Juan CBM – 4,500 mg/l
  - Greater Green River – 8,000 mg/l
  - Eagle Ford Shale – 20,000 mg/l
  - Fayetteville Shale – 25,000 mg/l
  - Barnett Shale – 60,000 mg/l
  - Woodford Shale – 110,000 mg/l
  - Haynesville Shale – 120,000 mg/l
  - Permian Basin – 140,000 mg/l
  - Marcellus Shale – 180,000 mg/l

Source: USGS
Key Water Management Concerns

- Increased regulatory scrutiny
  - Access to freshwater supplies for fracturing
  - Strict TDS discharge limits
- Limited disposal capacity
- Limited off site treatment options
- Long haul distances to adjacent wells
- Shallow groundwater quality impacts

BOTTOM LINE:
- Unconventional gas resources are driving development; and water solutions are key
- Water quality concerns leading to more treatment and reuse
  Solutions can be simple to very complex – *Reduce, Reuse, Recycle* are key goals
- At current natural gas prices, capital and O&M costs are very important
Design Basis
Critical First Step

- Feed Water Volume
- Feed Water Quality
- Treated Effluent Requirements
- Site Specific Considerations
Flowback/Produced Water Water Management Solutions

- **Treatment for Reuse**
  - Oil/Grease
  - TSS
  - Bacteria

- **Treat for Discharge**
  - Same as Reuse, Plus:
  - Removal of TDS
TREATMENT FOR REUSE
WITHOUT TDS REMOVAL
Range of Applicability vs. Cost

- **RO**
- **Evaporation**
- **Crystallization**

Total Dissolved Solids (mg/L TDS)

- Treatment for Reuse
- No TDS Removal
- TDS Removal

$ Costs per Barrel

- 750
- 3,000
- 40,000
- 260,000
- 1,000,000
Example Feed Water Quality

- **Water May Also Contain:**
  - Polymers
  - Other Organics
  - Radium
  - Other Inorganics (e.g., boron)

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Example Treatment Requirements

- pH: 6.5 to 7.5
- Iron: < 10 mg/L
- TSS: < 50 mg/L
- Bacteria: None
- Treatment Residuals: Non-hazardous
- Mobile system required (5,000 to 10,000 BWPD)
# Treatment Technology Options

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Example of Reuse Treatment Solution Without TDS Removal

Frac Flowback Water

Chemical Oxidation

Free Oil and TSS Removal

TSS and O/G Polish

Disinfection

Oil Byproduct

Sludge for dewatering/disposal

Treated Water

Sand Filter: TSS Removal

Chlorine Dioxide

Air

Chlorine Dioxide

Dissolved Oxygen
Step 1. Chlorine Dioxide Oxidation

- Chlorine dioxide is a strong oxidant that provides selective chemical oxidation.
- Breaks oil / grease emulsions.
- Destroys friction reducers and other chemical additives.
- Kills Bacteria.
- Oxidizes reduced compounds, such as Fe, Mn, Sulfide, etc.
- More efficient than bleach – does not react with ammonia and many other organics.

Ref: Sabre Technologies
Step 2. Dissolved Air Flotation

- Fine bubble diffusion floats oil / grease and TSS to top
- Skimmer potentially recovers saleable oil
- Covered designs also available for VOC emission control
- Skid-mounted design

NOTE: Dissolved Gas or Induced Gas Flotation may also be considered
Step 3. Multi-Media Sand Filtration

- Conventional sand filter removes TSS before reuse
- Acid or carbon dioxide addition ahead of filter to reduce pH and eliminate calcium carbonate scaling
- Periodically backwashed with filtered water. BW returned to front of system.
- Chlorine dioxide disinfection of final product water
Summary of Reuse Treatment

Without TDS Removal

• Simplest and least expensive form of treatment
• Multiple technology and design options available
• Reduces fresh water makeup requirements and off-site disposal costs
• Applicable only if drilling operations that need frac flowback water are on-going
• Bench and pilot-scale testing recommended to select best treatment options and minimize cost
TREATMENT OPTIONS FOR TDS REMOVAL
Viable TDS Removal Alternatives

- Membrane Treatment
- Evaporation
- Crystallization
Range of Applicability vs. Cost

- RO
- Evaporation
- Crystallization

$ Costs per Barrel

Total Dissolved Solids (mg/L TDS)

- Treatment for Reuse
- RO
- Evaporation
- Crystallization

750  3,000  40,000  260,000  1,000,000
Reverse Osmosis

- Membrane separation technology that removes dissolved solids (TDS) from water
- Membrane is semi-impermeable - allowing only water to pass; 99%+ of all ionized species are rejected
- Non-selective treatment process
- Degree of all ion rejection is dictated by size and charge
- NF is a loose RO membrane
Reverse Osmosis (continued)

- Maximum concentrate TDS is approx. 80,000 mg/L
- Energy costs are $1/10^{th}$ to $1/15^{th}$ the cost of mechanical evaporation
- Skid-mounted, compact design
- Operating pressures up to 1200 psig
- Multiple membranes and manufacturers available
Historical Problems with RO Treatment for Produced Water

- Limited success due to inadequate pretreatment, resulting in fouling and scaling from:
  - Calcium Hardness
  - Iron
  - Barium and Strontium
  - Silica
  - Microbiological Growth
  - Organics
  - Silt and Suspended Solids
Key to Success: Efficient Pretreatment

- Pretreatment Steps:
  - Organics removal (oil / grease, polymers, etc.)
  - Efficient management of hardness and metals
  - Particulate removal
  - Bacteria control

Result: Better pretreatment leads to less membrane fouling, higher water recovery and a lower cost of brine disposal
Example Treatment Solution for TDS Removal

- Frac Flowback Water
  - Chlorine Dioxide
  - Air

- RO: TDS Removal
  - Sludge for dewatering/disposal

- Cartridge Filtration: TSS Polish
  - Anti-scalant
  - Sulfite

- Sand Filter: TSS Removal
  - Chlorine Dioxide

- Treated Water

- Brine Conc.

Byproduct: Oil
Range of Applicability vs. Cost

- **Evaporation**
  - Total Dissolved Solids (mg/L TDS): 40,000
  - Costs per Barrel: 750

- **RO**
  - Total Dissolved Solids (mg/L TDS): 3,000
  - Costs per Barrel: 3,000

- **Crystallization**
  - Total Dissolved Solids (mg/L TDS): 260,000
  - Costs per Barrel: 1,000,000

- **Treatment for Reuse**
  - Total Dissolved Solids (mg/L TDS): 1,000,000
  - Costs per Barrel: 30
Evaporation

- Ideal TDS Range of Feed Water is 40,000 to 120,000 mg/L
- Produces high quality distillate and liquid brine concentrate
- Brine concentrate requires further treatment or disposal (max TDS concentration is approx. 260,000 mg/L)
- Evaporation systems more energy intensive than RO
- Most evaporation systems cannot handle any TSS
Types of Evaporation Systems

- Forced Circulation
- Falling Film
- Rising Film
- Agitated Thin Film
- Plate and Frame
Selection Considerations

- Chemical Composition of Feed Stream
- Scaling / Fouling Potential
- Foaming Potential
- Materials of Construction
  - Chloride concentrations
  - Temperature
Economization

- **Multiple Effects**
  - Vapor From Each Effect is used in the Next / Previous Effect Depending on Set-up to Reduce Steam Use

- **Vacuum**
  - Reduces Boiling Point
  - Maximizes Efficiency When Used in Concert With Multiple Effects

- **Mechanical Vapor Recompression**
  - Recompresses the Vapor to Reduce Steam Use
  - Usually Uses Just One Effect
MVR Evaporator
Most Economical for this Application
Range of Applicability vs. Cost

Costs per Barrel

Total Dissolved Solids (mg/L TDS)

- Treatment for Reuse
- Evaporation
- RO
- Crystallization

- 750 - 3,000 - 40,000 - 260,000 - 1,000,000
Crystallizer

- Complex system capable of producing purified salt **products** from impure solutions
- Multiple Types of Crystallizers available
- Principals of Crystallization include:
  - Evaporation to form supersaturated solution
  - Nucleation and growth of salt crystals
  - Harvesting, washing and drying of salt crystals
Application of a Crystallizer in the Marcellus

- **Crystallizer Products:**
  - Calcium Chloride Liquid
  - Sodium Chloride Dry Salt
  - Distilled Water

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<td>Chloride</td>
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</tr>
<tr>
<td>TSS</td>
<td>295</td>
</tr>
<tr>
<td>TDS</td>
<td>132,265</td>
</tr>
</tbody>
</table>
Crystallizer Block Flow Diagram

Feed Water → Pretreatment → Evaporator → Crystallizer → Centrifuge

- Chemicals
- Waste Sludge
- Liquid Waste Purge
- Distilled Water → Reuse/Discharge
- Calcium Chloride Liquid (28-40%) → Drilling Fluid or Road Deicing
- Sodium Chloride Dry Salt (99+%) → Road Salt
Key Considerations

- Proper Design
- Feed Water Management
- Economics – Byproduct Chemical Sales (ASTM specifications)
• RO membranes have found little use in the Marcellus
• Evaporation technology using Mechanical Vapor Recompression most common form of TDS Treatment
• Crystallization technology is complex but can be cost effective with sale of commodity chemical byproducts
• All technologies generally produce some amount of waste brine that requires disposal
Questions and Answers

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