Water Treatment for Hydraulic Fracturing Operations

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Cetco
In this presentation, the major technologies that are likely to dominate recycling of HF flow back fluids are discussed.

These are:

- Coagulation / Flocculation & Electrocoagulation
- MVC – Mechanical Vapor Compression
- Ceramic Membranes and other Media
- Biotreatment
- + oxidation, biological control, scale control
There are three aspects of hydraulic fracture flow back that are driving the industry to select these technologies.

These are:

- High volumes of water
- Three stages of field development
- High concentration of organic and inorganic TSS
Water Volumes in Unconventional are a Game Changer

Conventional HF in the US: 1 MM wells
Conventional HF outside the US: 1.5 MM wells

This suggests that there is a huge body of experience in managing, handling, treating, and recycling HF flow back fluids.

But the volumes of water involved in Unconventional are a Game Changer:

- Unconventional HF: 120,000 bbl (20 ML)/job
- Conventional HF: 2,000 bbl (320 kL)/job
Conventional Offshore HF Flow Back – as a possible analog?

Compact, simple, reliable systems for stranded water

Most systems involve pre-treatment and some form of media

<table>
<thead>
<tr>
<th></th>
<th>Vendor 1</th>
<th>Vendor 2</th>
<th>Vendor 3</th>
<th>Vendor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td>Weirbox + Filters + Media + AC</td>
<td>Weirbox (w/coalescer pad) + Filters + Media + AC</td>
<td>Surge tank + CINC Centrifuge + Media + AC</td>
<td>Separator (w/ plates and coalescer pad) + Media + AC</td>
</tr>
<tr>
<td><strong>Form</strong></td>
<td>Granules</td>
<td>Cloth</td>
<td>12 x 20 granules</td>
<td>Granules</td>
</tr>
<tr>
<td><strong>Regenerable?</strong></td>
<td>No</td>
<td>No</td>
<td>Backwash/rinse</td>
<td>No</td>
</tr>
<tr>
<td><strong>Design criteria</strong></td>
<td>2 BPM</td>
<td>5 gpm/ft²</td>
<td>13.5 gpm/ft²</td>
<td>2 gpm/ft²</td>
</tr>
<tr>
<td><strong>Flow direction</strong></td>
<td>Radial O→ I</td>
<td>Radial O→ I</td>
<td>Down</td>
<td>Up</td>
</tr>
</tbody>
</table>
Ranking of Produced Water Treatment Challenges

Costs are for CAPEX and OPEX including services, logistics, and modularization.

- Oily water / injection
- Oily water / overboard discharge
- Oily HF FB / overboard
- HF FB/desal ZLD Centralized
- Oily high Cl / overboard
- HF FB/ desalination ZLD remote
- Shale slickwater / TSS reduction recycle
- Shale guar / TSS reduction recycle
- Polymer flood / reinjection
- Oily water / overboard discharge
- Oily water / injection
As far as water treatment is concerned, there are only two types of flow back fluid:

1) Slickwater fluids
   moderate TSS: 500 – 1,000 mg/L
   well understood

2) Polysaccharides (guar, HEC, xanthan)
   very high TSS: 2,000 – 8,000 mg/L
   high fouling tendency

Nothing else needs be considered due in part to variability of flow back fluids.
Food Processing: high organic TSS

High loading of dissolved and suspended biodegradable contaminants

Anaerobic + aerobic activated sludge

Ref.: Powell Water Systems Inc.
Pulp and Paper: high loading of polysaccharides

COD = 1,000 to 5,600 mg/L

Lower COD: Chemical oxidation + coagulation: 50 % COD removal

Higher COD: Chemical oxidation + anaerobic / aerobic activated sludge: 90 % COD removal

DAF + chemical precipitation: 60 % COD removal

Ref.: Pokhrel, Treatment of Pulp and Paper Wastewater – A Review
Primary Treatment Flow Diagram – Example

- **Rapid Mix Tank**
- **Reaction Tank**
- **Gravity Clarifier**
- **pH Adjustment Tank**
- **Final Filters (optional)**

- **Influent**
- **Sludge Tank**
- **Sludge Press**
- **Sludge cake To disposal**
- **Treated effluent**

- **Na₂CO₃**
- **Polymer**
- **HCl**

Ref.: Shell report
Three Stages of Field Development:
(defined in terms of type of water treating equipment)

1) Remote and isolated well development –
   mobile water treating systems

2) Well clusters with some in-field drilling and completions –
   modular water treating systems

3) Extensive in-field development with infrastructure –
   networked conveyance systems
   centralized water treating plants
Initial stage of field development:
a few isolated well pads
no water infrastructure

1st well:
Stranded Water

Producing wells
HF flow back

In-Field Processing
Mobile Units

2nd well:
opportunity to recycle

Disposal well

isolated and remote water treatment:
reduce or eliminate need for disposal
provide fracturing fluids for next well (recycling)

Distance from well to treatment < 2 miles
**Mobile Technology**

Fountain Quail / Aqua-Pure ROVER Mobile Clarifier – TSS (solids and organics) are chemically precipitated. Solids settle conveyed to filter press, ultimately to cuttings box. 90 % removal of TSS. Capacity is 10 kBWPD (7 BPM).

GE Mobile Evaporation – Truck-mounted MVR with horizontal shell in tube Hex. Capacity 1 BWPM.

Mobile Electrocoagulation units: Halliburton, Cetco – reduced chemical consumption, 90% removal of TSS.
Some in-field development:
- well clusters
- modular water treating units
- no water infrastructure

Producing wells
- HF flow back

Fast Line / Flexi-hose
- between holding ponds and wells

In-Field Processing Modular Units
- Well clusters
- Full Treating is an Option
- Facilitates several disposal options

modular water treatment:
- larger than mobile, requires set-up
- reduce or eliminate need for disposal
- provide fracturing fluids for next well (recycling)

Distance from well to treatment < few miles
Semi – Centralized / Modular Treatment Facilities

Barnett Shale: Semi – Permanent evaporation facilities using Fountain Quail NOMAD MVR evaporation technology. Capacity ~ 20 kBWPD.

Marcellus Eureka Resources Facility: Semi – Permanent facilities NOMAD.
## Comparison of Thermal Desalination Techniques

<table>
<thead>
<tr>
<th></th>
<th>MED</th>
<th>TCD (MED-TVC)</th>
<th>MVC</th>
<th>RO</th>
<th>MSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant depreciation</td>
<td>10 % per annum</td>
<td>0.90</td>
<td>0.60</td>
<td>0.80</td>
<td>0.48</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.022 US$/kWh</td>
<td>0.022</td>
<td>0.022</td>
<td>0.308</td>
<td>0.088</td>
</tr>
<tr>
<td>Sea water</td>
<td>0.028 US$/m³</td>
<td>0.196</td>
<td>0.084</td>
<td>0.056</td>
<td>0.084</td>
</tr>
<tr>
<td>Steam</td>
<td>3.616 US$/tonne</td>
<td>0.58</td>
<td>0.58</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.024</td>
<td>0.024</td>
<td>0.016</td>
<td>0.03</td>
<td>0.015</td>
</tr>
<tr>
<td>O &amp; M</td>
<td>3 % of investment /year</td>
<td>0.27</td>
<td>0.18</td>
<td>0.24</td>
<td>0.144</td>
</tr>
<tr>
<td><strong>Total cost USD / m³</strong></td>
<td><strong>2.0</strong></td>
<td><strong>1.5</strong></td>
<td><strong>1.4</strong></td>
<td><strong>0.8</strong></td>
<td><strong>1.8</strong></td>
</tr>
<tr>
<td><strong>Total cost if steam is free</strong></td>
<td><strong>1.4</strong></td>
<td><strong>0.9</strong></td>
<td><strong>1.4</strong></td>
<td><strong>0.8</strong></td>
<td><strong>1.2</strong></td>
</tr>
</tbody>
</table>
Networked Water
a few large scale treatment sites

Centralized Processing
CWT / POTW

Full Treating is an Option
Lower treatment cost
Higher gathering cost
Requires a network
Facilitates fill re-cycle

Centralized Distance to treatment facility > 20 miles

Pinedale
Pinedale – Further Refinement

Note the additional treatment steps employed for RO reject (brine). This greatly reduces the volume of reject from the facility. Overall recovery is 84 to 90% of feed.

Also note the use of Electrocoagulation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Plant Feed Range</th>
<th>WYPDES Discharge Limits</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>O&amp;G, mg/l</td>
<td>50–2,400</td>
<td>10</td>
<td>Non-Detect</td>
</tr>
<tr>
<td>TDS, mg/l</td>
<td>8,000–15,000</td>
<td>500</td>
<td>41</td>
</tr>
<tr>
<td>Chloride, mg/l</td>
<td>3,600–6,750</td>
<td>230</td>
<td>18</td>
</tr>
<tr>
<td>Sulfate, mg/l</td>
<td>10–100</td>
<td>3,000</td>
<td>Non-Detect</td>
</tr>
<tr>
<td>Conductivity, µS/cm</td>
<td>8,000–20,000</td>
<td>7,500</td>
<td>78</td>
</tr>
<tr>
<td>pH</td>
<td>6.5–8.5</td>
<td>6.5–9</td>
<td>7.34</td>
</tr>
</tbody>
</table>
The Progression of Stages in HF Water Treatment

Increasing distance between well and water treatment

- **In-Field Processing**
  - Mobile Units

- **In-Field Development**
  - Modular Units
  - Well clusters
  - Full Treating is an Option

- **Centralized Processing**
  - CWT / POTW
  - Full Treating is an Option
  - Lower treatment cost
  - Higher gathering cost
  - Requires a network
  - Facilitates fill re-cycle

- **Stranded Water**
  - Mobile Units

- **Clustered Water**
  - Modular Units

- **Networked Water**
  - Centralized Treatment

Increasing distance between well and water treatment
Cost versus Stage of Field Development:

Field development timeline

- Stranded Water
- Clustered Water
- Networked Water

Water Treatment Cost

Connectedness of Water System

Number of Treatment Options

Cost

Water Network Connectedness

Number of Treatment Options
The dominant technologies for HF flow back water treatment for recycling will be:

1) MVR for desalination – modular & centralized
3) Coagulation / Flocculation, EC and ceramic membranes for mobile and modular TSS removal
3) Biotreatment for centralized TSS removal

Other specialized technologies will be applied for breaking the polymer (oxidation), biological control (ozone, on-site chlorine generation) and for scale control (mostly chemicals)
The End