Bob Long,
Director of Technology

SWD MANAGEMENT AND INJECTIVITY

Bob Long,
Director of Technology
Phase Change

- **Equilibrium**
- **Critical Point**
- **Triple Point**

Key Processes:
- Melting
- Freezing
- Condensation
- Sublimation
- Deposition

**Axes:**
- P (atm)
- T (°C)
Methods used to quantify Solids and phase change

- Oil Analysis for Paraffin and Asphaltene content
- Water Analysis for Total Dissolved Solids
- BS&W centrifuge for % Suspended Solids
- Millipore for low level Total Suspended Solids
- Deposition coupons for what isn’t suspended
- Corrosion for increased corrosion by products
- Extended Filter studies for Suspended Solids
Oilfield Solids

- Paraffin and Asphaltenes
- Mineral Scales such as Barite (BaSO$_4$) and Calcite (CaCO$_3$)
- Formation fines such as Sand and Silts
- Iron Scales such as:
  - Siderite (FeCO$_3$) commonly called Iron Carbonate
  - Ferrous Sulfide (FeS) or Iron Sulfide is Amorphous
  - Greigite (Fe$_3$S$_4$) is a crystalline Iron Sulfide Species
  - Magnetite (Fe$_3$O$_4$) or Iron Oxide
  - Pyrrhotite (Fe$_7$S$_8$) is another more stable crystal scale
  - Pyrite iron(II) disulfide, FeS$_2$ (cubic), the more stable endmember, known as fool's gold.
What Is it? Methods to ID

- Wet Bench or Solvent Soak Tests
- X-ray Diffraction Molecular ID for crystalline
- EDX / XRF for amorphous Solids
- SEM for visual ID
- Particle Size Analysis
## EDX / SEM – Deposit Analysis

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<th>Element Line</th>
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Properly Identifying the debris and Quantity
Millipore and XRF

Pre Filter

- Iron (35%)
- Sulfur (29%)
- Silicon (14%)
- Chloride (9%)
- Zinc (6%)
- Phosphorous (2%)
- Calcium (5%)

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<td>Zinc (Zn)</td>
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<td>Chloride (Cl)</td>
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X-Ray Diffraction
# XRD – Deposit Analysis

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<th>Quartz SiO2</th>
<th>Sr-Barite Ba0.75Sr0.255SO4</th>
<th>Aragonite CaCO3</th>
<th>K-Feldspar KAISI3O8</th>
<th>Mg-Calcite (Ca,Mg)CO3</th>
<th>Siderite Fe++CO3</th>
<th>Anhydrite CaSO4</th>
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DETERMINING THE ROOT CAUSE
AND MORE EFFECTIVE SOLUTIONS
TO PREVENT SOLIDS.
Root Cause Solutions

1. Map the Process Flow with T & P
2. Develop a monitoring and system survey plan
3. Walk the pipe & process flow with Operations
4. Compile all historical data and failure info
5. Methodically collect a baseline of statistically valid data.
6. Develop a root cause solution with operations
7. Implement a trial of one solution at a time
8. Minimizes other system changes while collecting comparative data
Investigative Tests

• CO$_2$ and H$_2$S Levels
• Water Analysis
• Millipore TSS
• BS / BS&W %
• Deposit ID
• Bacteria Survey
• Scale Deposition Rate
• Pitting Corrosion Rate
• General Corrosion Rate
• Dissolved Oxygen
• Chemical Residuals
• Oil Content in water
• Soluble oil & Grease
• Interfacial vessel pads
## Finger Printing Sources

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<th>Well</th>
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<th>TotFld (BBLs)</th>
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<th>Paraffin lbs/D</th>
<th>Scale lbs/D</th>
<th>Sand lbs/D</th>
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Programs to Prevent Solids

- Iron Inhibitors to keep in solution
- Corrosion Inhibitors
- Scale Inhibitors
- Scavengers to prevent Sulfides and Oxides
- Salt Inhibitors and Fresh Water Wash
- Complete Kill Biocide programs
- Wax Inhibitors
EXAMPLE CASE STUDIES

AND

RETURN ON INVESTMENT
ROI Benefits for Programs

- Reduced costs of solids waste handling
- Eliminating or reducing Acids, EBs and Clarifiers
- Preventing the need for Capital Expenses
- Prevention of decreased production / down time
- Reduced Operating costs like:
  - Energy Savings
  - Heating Emulsions
  - Pump maintenance.
  - Acid or Coil Tubing jobs
“Offshore– Case Study”

Operators Issues:

- Over Pressured Salt Water Disposal (SWD) wells
- Coil tubing remediation clean outs
- Loss of revenue, with high Oil PPM being disposed of
- Solids disposal and clean out of separators and Skimmer
- Increased water pump failures due to erosion
- Continued loss of well Injectivity after clean outs
- Field became production limited, with water disposal limitations
Offshore – Case Study

Survey result summaries:

- Separators & vessels not functioning due to scale buildup
- Water was corrosive, adding Iron to the system
- Dissolved Oxygen intrusion was further precipitating Iron
- Ineffective biocide program applied downstream of contaminated vessels and equipment.
- Paraffin program was downstream of problem
- Scale Inhibitor, was applied after precipitation
- No effective KPIs to manage chemical programs
Solutions:

- Combination Iron, Corrosion and Scale Inhibitor was applied upstream of separators
- SWD surfactant program was discontinued
- Emulsion Breaker was discontinued in summer months and not needed on most separators during winter
- Separators and water skimmer were cleaned up
- Extensive monitoring was done with KPIs added
- Operator adding chemical captain to own programs
# Return on Investment

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<tr>
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<th>$ Prior</th>
<th>$ After</th>
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<td>Reparing SWD pumps</td>
<td>$40,000</td>
<td>$40,000</td>
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<tr>
<td>SWD Coil Tubing Job</td>
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<td><strong>Gains</strong></td>
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<td>Remove 400 ppm oil</td>
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<td><strong>Gains</strong></td>
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<td>$ After</td>
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<td><strong>New Investment</strong></td>
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**Net Gain** $233,600

## ROI = 146 Percent with a 0.41 Year Payback

\[
\text{ROI} = \frac{\text{Gains ($160,000)} + \text{Revenue ($233,600)} - \text{Investment ($160,000)}}{\text{Investment($160,000)}} = 146\% \\
\text{Payback Period} = \frac{\text{Investment ($160,000)}}{\left[ \text{Gains ($160,000)} + \text{Revenue ($233,600)} \right]} = 0.41 \text{ Years}
\]

### Comments:
- Chemical Savings in 2014 over X-chem 2013 and 2012 usage
- Projected Annual Usage Cost = $150000
- SWD Remediation clean out job with Coil Tubing job
- SWD Pump repair estimate, need to decrease

**Note**: All dollar values must be annualized.

20,000 BWPD x 400 ppm x 365 x $80 barrel = $233,600

**Revision: 2.1**
Operators Issues:

- Plugging up Water Flood and SWD wells
- Oil wet Solids
- Solids causing high filter costs
- Coil tubing interventions at $5,000,000 / year
- Excessive filter costs
- lost revenue from Water Flood
## Filter Study

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<th>Post Weight</th>
<th>Delta</th>
<th>Volume (Liters)</th>
<th>TSS (mg/L)</th>
<th>TOTAL SOLIDS</th>
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<td>Plains Pre Filter 8.0 Filter</td>
<td>0.1313</td>
<td>0.1566</td>
<td>0.0253</td>
<td>1</td>
<td>25.3</td>
<td>14,932 lbs/yr</td>
</tr>
<tr>
<td>Plains Train II Post Filter 8.0 Filter</td>
<td>0.1315</td>
<td>0.1493</td>
<td>0.0178</td>
<td>1</td>
<td>17.8</td>
<td>10,505 lbs/yr</td>
</tr>
<tr>
<td>Plains Pre Filter 8.0 Filter</td>
<td>0.0596</td>
<td>0.1304</td>
<td>0.0708</td>
<td>1</td>
<td>70.8</td>
<td>41,904 lbs/yr</td>
</tr>
<tr>
<td>Plains Train II Post Filter 8.0 Filter</td>
<td>0.0600</td>
<td>0.0940</td>
<td>0.0340</td>
<td>1</td>
<td>34</td>
<td>20,066 lbs/yr</td>
</tr>
</tbody>
</table>
Identifying the filtered solids

<table>
<thead>
<tr>
<th>Results*</th>
<th>K-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (% as Fe)</td>
<td>67</td>
</tr>
<tr>
<td>Chloride (% as Cl)</td>
<td>9</td>
</tr>
<tr>
<td>Sodium (% as Na)</td>
<td>3</td>
</tr>
<tr>
<td>Calcium (% as Ca)</td>
<td>5</td>
</tr>
<tr>
<td>Sulfur (% as S)</td>
<td>9</td>
</tr>
<tr>
<td>Silicon (% as Si)</td>
<td>4</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning (weight in g)</td>
<td>N/A</td>
</tr>
<tr>
<td>Ending (weight in g)</td>
<td>N/A</td>
</tr>
<tr>
<td>Deposit (weight in g)</td>
<td>N/A</td>
</tr>
<tr>
<td>Volume (in mL)</td>
<td>N/A</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**K-4 Pie Chart**
- Iron (% as Fe): 67%
- Chloride (% as Cl): 9%
- Sodium (% as Na): 3%
- Calcium (% as Ca): 5%
- Sulfur (% as S): 9%
- Silicon (% as Si): 4%
Calculating the Injectivity index ($II$) is the most common way of analysing performance of injection wells. The calculation can be made from only the most basic data: injection rate ($Q$), injection pressure $P_{wf}$ (corrected for bottom hole flowing conditions), and far-field reservoir pressure $P_e$. In oilfield units, the Injectivity index is commonly calculated as:

$$II = \frac{Q}{P_{bhi} - P_e} = \frac{k_w \cdot h_i}{141.2 \cdot \mu_w \cdot B_w \cdot \left( \ln \frac{r_e}{r_w} + S \right)}$$

where $Q$ is in STB/d and $P$ in psia. Additional data required includes permeability $k_w$ in md, water viscosity $\mu_w$ in cp, water FVF $B_w$ (res vol/STC vol), wellbore and drainage radii $r_w$ and $r_e$ in ft, and injection height $h_i$ in ft. The term $S$ denotes the total near-wellbore skin which may be composed of mechanical (completion) skin, plugging, fracturing, and flow related skin (turbulence).
Injectivity Losses

Injectivity = \frac{BWPD}{P}
Injectivity Repair

Treated with 50 Gals E-2410
Injectivity Repair

Treated with 50 Gals E-2410
Any questions?

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