Well Integrity Assurance: A Successful Method for External Corrosion and Damage Detection on Outer and Middle Concentric Strings of Casing

SPE no. 108698
MJ Loveland
Joey Burton
13NOV07
Shallow External Casing Corrosion

- To Initiate Corrosion...
  - Just Add Water
    - Large Water Surface and Open Air Flow Path
    - Re-generates Oxygen Content

Note Oxygen Enriching Algae in Water
Shallow External Casing Corrosion
Galvanic cell is created from presence of electrolyte, oxygen and sacrificial anode (surface casing)

Heat Increases Corrosion Rate
Single Casing Completion with Hot Water Injection
Higher Temperature Gradient = Faster Thermo-Galvanic Corrosion
Recent SC failures prompted the search for a method to determine corrosion severity on the middle concentric ring of casing.
Tool Description

- Memory Tool
- Generates an alternating magnetic wave
- Wave is detected on one of 12 sensor arrays when it completes its path
- Wave velocity and amplitude is affected by metal thickness
- Sensor next to an area with metal loss receives wave back quicker than area with no metal loss
Tool Development

- Originally developed to assess single tubular applications to provide an absolute remaining wall thickness
  - Useable transmission frequency ranges from 8 to 16 Hz.
  - Higher frequencies provide for greater vertical detail of anomalies, but reduce the overall amount of metal that the signal can effectively travel through.
  - Lower frequencies can effectively travel through higher metal volumes, but provide less detail of recorded anomalies.
Concentric casing applications

- Provide a Qualitative metal loss from all 3 strings of casing
- For intervals < 500’ complete 3 passes using lower frequency spread 8, 10, and 12 Hz.
- Sharper features at higher frequency are most likely inner concentric strings
- Features more prevalent at lower frequency are more likely from outer concentric strings
Logging/Excavation Plan

- Log was run on 7 wells with 3 concentric strings near surface scheduled for excavation repair.

- Compared to results of visual inspection
Comparison of Visual Inspection to Log Results in Well A

**Average Metal Response**

<table>
<thead>
<tr>
<th>-50 Delta Metal Thickness (%)</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Line Speed (ft/min)</td>
<td>-200</td>
</tr>
</tbody>
</table>

Photo of Corrosion & Holes in Surface Casing @ 21.5'
Comparison of Visual Inspection to Log Results in Well B

<table>
<thead>
<tr>
<th>Average Metal Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>-50</td>
</tr>
</tbody>
</table>

- Tree
- Tubing Hanger
- Pup Jt.

- 3.5" Collar
- 13% Metal Loss
- 15% Metal Loss

- Line Speed
- 10'
- Jt. 1
- 20'
- 30'
- Pup Jt.
- Pup Jt.
- Pup Jt.

Photo of Corrosion & Holes in Surface Casing @ 7' - 8'
Comparison of Visual Inspection to Log Results in Well C

Photo of Corrosion & Crack in Surface Casing @ 5'

Comparison of Visual Inspection to Log Results in Well D

Photo of Corrosion & Hole in Surface Casing @ 6'
<table>
<thead>
<tr>
<th>Well</th>
<th>Reason</th>
<th>TYPE</th>
<th>SC (in.)</th>
<th>CC (in.)</th>
<th>Tubing (in.)</th>
<th>COMMENTS / STATUS</th>
<th>Patch Repair status</th>
<th>Caliper Data</th>
<th>Log vs Visual Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>8% metal loss from 18-26’</td>
<td>Done</td>
<td>shallow pitting pits up to ~2 % metal loss</td>
<td>Excellent</td>
</tr>
<tr>
<td>B</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>13% metal loss from 3.5-12’ 15% metal loss from 18-29’</td>
<td>Done</td>
<td>pits w/ 6% metal loss at 32’</td>
<td>Excellent</td>
</tr>
<tr>
<td>C</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>12% metal loss from 4-8’</td>
<td>Done</td>
<td>shallow pitting up to ~2 % metal loss</td>
<td>Excellent</td>
</tr>
<tr>
<td>D</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>8% metal loss from 4'-10’</td>
<td>Done</td>
<td>no data near surface</td>
<td>Excellent</td>
</tr>
<tr>
<td>E</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>7% metal loss from 4-10’</td>
<td>Done</td>
<td>shallow pitting pits ~2 -5% % metal loss</td>
<td>Excellent</td>
</tr>
<tr>
<td>F</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>7% metal loss at 7” 6% metal loss from 10-20’ may be tubing damage</td>
<td>Done</td>
<td>shallow pitting up to 4% metal loss</td>
<td>Excellent</td>
</tr>
<tr>
<td>G</td>
<td>Failed</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>8% metal loss from 3-10’ 13-15% metal loss from 20-40’ - some loss may be tubing wall</td>
<td>Done</td>
<td>shallow pitting 2 6% metal loss</td>
<td>Excellent</td>
</tr>
<tr>
<td>H</td>
<td>Proactive</td>
<td>Gas Lift</td>
<td>7.625</td>
<td>16</td>
<td>2.875</td>
<td>2% metal loss from 10-12’ Noisy - hard to interpret - may be the 7 5/8” x 2 7/8” combo</td>
<td>Not needed</td>
<td>none</td>
<td>Good</td>
</tr>
<tr>
<td>I</td>
<td>Proactive</td>
<td>Jet Pump</td>
<td>7.625</td>
<td>16</td>
<td>3.5</td>
<td>16% metal loss from 0-3’ metal loss my be exaggerated by larger size casing or tubing corrosion is also present</td>
<td>Done</td>
<td>none</td>
<td>Good</td>
</tr>
<tr>
<td>J</td>
<td>Proactive</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>5% metal loss at 1’</td>
<td>Done</td>
<td>shallow pitting up to ~3% metal loss</td>
<td>Good</td>
</tr>
<tr>
<td>K</td>
<td>Proactive</td>
<td>INJ</td>
<td>5.5</td>
<td>13.375</td>
<td>3.5</td>
<td>8% metal loss from 0-2’ some wall loss may be tubing</td>
<td>Not needed</td>
<td>shallow pitting up to 4% metal loss</td>
<td>Poor</td>
</tr>
<tr>
<td>L</td>
<td>Proactive</td>
<td>INJ</td>
<td>5.5</td>
<td>16</td>
<td>3.5</td>
<td>15% metal loss at 4’ Results really hard to read Possible line speed issues</td>
<td>Done</td>
<td>shallow pitting up to ~2 % metal loss</td>
<td>Poor</td>
</tr>
</tbody>
</table>
# Correlation Confidence

<table>
<thead>
<tr>
<th>Casing Configurations</th>
<th>Well Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>CC (in.) SC (in.) Tubing (in.) Logs Run Visually inspected Correlation confidence</td>
<td></td>
</tr>
<tr>
<td>16 8.625 3.5 1 NA</td>
<td></td>
</tr>
<tr>
<td>16 7.625 2.875 1 1 Not yet</td>
<td></td>
</tr>
<tr>
<td>16 7.625 4.5 4 NA</td>
<td></td>
</tr>
<tr>
<td>16 7.625 3.5 2 1 Not yet</td>
<td></td>
</tr>
<tr>
<td>16 5.5 3.5 16 9 Yes</td>
<td></td>
</tr>
<tr>
<td>13.375 5.5 3.5 1 1 Not yet</td>
<td></td>
</tr>
</tbody>
</table>
Sharp features are generally the innermost string where more spread out response appears to correlate with middle and outer concentric casing.

SC casing collar and standing plate are in the same location masking SC damage.
Complicating Factors – Physical Issues

Cement Circulation ports can be clearly identified on sensors 1 and 12.
Complicating Factors – Physical Issues

Elevated Metal Response on Sensor #11 Corresponds to ESP Power Cable

-50 Delta Metal Thickness (%) 50

<table>
<thead>
<tr>
<th>1.8</th>
<th>MTTP01 (rad)</th>
<th>11.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>-7</td>
<td>MTTP12 (rad)</td>
<td>3</td>
</tr>
</tbody>
</table>

-7 5/8” Casing Collar

-7 5/8” Casing Collar

-7 5/8” Casing Collar
Assumption

- Baseline area has 100% metal thickness
One Data Set Calibrated at Two Different Depths

Possible Well Condition

Actual Confirmed Well Condition
Tool Limitations

- Tool overwhelmed in intervals with
  - 4 concentric casing strings
  - Some 3 concentric casing with large casing sizes.

- Inverted Tool response
  - Noted in some wells w/ 3 concentric rings w
Operational Issues

Erratic tool speed makes data impossible to interpret

Irregular tool speed should be evident real time on the wireline weight indicator and is subsequently more closely monitored
Summary

- Good qualitative approach to identify external corrosion and metal loss on middle and outer concentric casing strings.
- Tool works best in smaller casing configurations
- Highest correlation confidence in 16”x5.5”x3.5” tubulars
- Steady logging speed is required
- Used to estimate excavation depth and prioritize proactive inspections