Through-Tubing Casing Inspection: Methodology and Case Studies

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GOWell
The direct causes for the uncontrolled release of hydrocarbons for 111 days from SS-25 were:

- Axial rupture due to external microbial corrosion on the 7 in. casing OD caused by the groundwater.
  - Groundwater accessed the 11 3/4 in. x 7 in. annulus and provided an environment conducive to microbial corrosion.
- Carbon dioxide, a component of natural gas, seeped through the 7 in. casing connections and was likely a nutrient for the microbes.

Reference: https://www.cpuc.ca.gov/aliso/
EM Inspection Methods

Magnetic Flux Leakage

Remote Field Eddy Current (RFEC)

CIT – Casing Inspection Tool
HRVRT – HR Vertilog

MTT – Magnetic Thickness Tool
EMIT – EM inspection tool

Pulsed Eddy Current (PEC)

MTD – Magnetic Thickness Detector
ePDT – enhanced Pipe Detection Tool
Why use Pulsed Eddy Current?

- Same depth Tx and Rx coils
- Short High Energy Pulse
- Time Domain Received signal
- Measures multiple pipes

Ref: SPWLA 2014
How to read a PEC log?

Logs consists of:

1) VDL where
   - Green = Nominal pipe
   - Blue = Thickness gain
   - Red = Wall Loss
Left to Right is radial distance from tool

2) Average Thickness curve for each pipe

Red arrows indicate damage in 3-1/2” tubing

Blue arrows indicate damage in the 9-5/8” casing

Surface Test with 3-1/2” tubing and 9-5/8” casing
**Field Log**

Example of real-time field log showing 2\(^{nd}\) pipe corrosion

<table>
<thead>
<tr>
<th>LSPD</th>
<th>1650 COFS</th>
<th>2450</th>
<th>750</th>
<th>900</th>
<th>C Decay</th>
<th>QC C</th>
<th>5 A Decay</th>
<th>60</th>
<th>QC A (mV) 300</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20 (ft/min) 20</td>
<td>0 CNOIS10000</td>
<td>1850 AOF</td>
<td>2250</td>
<td>1</td>
<td>12</td>
<td>1 (mV) 45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GTC_GR (GAPI) 150</td>
<td>0 TellHeadV</td>
<td>0 ANOIS10000</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GTC_WTemp (degF) 150</td>
<td>MODE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Graph showing real-time field log data]

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Case Study #1 – Casing Break in CSS well

Cyclic Steam Stimulation wells

4-1/2” tubing and 9-5/8” Casing

Challenge: How to detect a casing break thru’-tubing thereby reducing workover costs?

Solution: Employ PEC tools for a regular surveillance program across the field
Case Study #1 – Casing Break in CSS well

MFC Verification during subsequent workover

Breach
Ultrasonic identified external corrosion in 7in across xx95ft. Pressure test confirmed a hole in the 7in casing. Thru’ tubing PEC log shows massive electro-chemical corrosion of the 9-5/8” casing behind a 7” production casing. The corrosion has also caused localized extensive 7” damage.
Case Study #3 – Casing Corrosion

1st - Logged in 7” + 9-5/8”

2nd - Logged in 9-5/8”

7” cut and pulled

Severe corrosion of the 9-5/8” casing below the 13-3/8” casing shoe

Corrosion Interval
Case Study #3 – Casing Corrosion

Electro-Magnetic thickness

7” + 9-5/8”

Ultrasonic Radius image

9-5/8”

Penetration

9-5/8” collar

7” collar
Case Study #5 – P&A or sidetrack planning

Field Log 7” and 9-5/8” Csg

Locate: joint connections, external hardware and shoe depths

4-1/2”, 7”, 9-5/8” and 13-3/8” Csg

4th Pipe (13-3/8”)
1st Pipe (4-1/2”)
2nd Pipe (7”)
3rd Pipe (9-5/8”)
4th Pipe (13-3/8”)
DV
Case Study #6 – Old Wells!

The well was spudded in 1924 by E. E. Tyler. Drilling proceeded intermittently over the following 12 years eventually reaching a total depth of 3550 ft (1082m) in 1936. The well was abandoned having reached the Upper Marine Series. Drilling was delayed at various times due to water issues, lack of funding and finally stopped completely due to inadequacy of plant. The top of the coal seam is believed to be at 1246 ft (378.0). No lithological log is available. A number of gas shows were encountered and whilst the driller reported oil shows, these could not be verified by government representatives. The likelihood of finding commercial supplies of petroleum appeared remote and there was a disagreement with the government representatives over chance of success.

**Inspection:** Well inspected on 29th May 2015. Audible subsurface water, potentially serious integrity issues. Cellar is 1.4 x 1.7m x 0.7m deep and partially collapsed. The annulus between the 11” conductor and 6” casing was investigated to a depth of 3m but no water was encountered.

1924 started drilling but took 12 years to reach 1082m

Reports are not available for this well. It appears that the well owner was an eccentric looking for oil. Govt was not convinced. Status of hole unknown and they should be inspected!

Case Study #8 – Logging in CRS Cr13 tubing?

PEC response decays quickly in CRS pipes.

Collars in CRS tubing – decay very quickly and don’t “show up” in 2nd pipe zone.

5-1/2” 13CR P110 Tubing
9-5/8” Casing

7” 13CR P110 Tubing
9-5/8” Casing
Case Study #9 – Corrosion Evaluation Comparison

Two Runs were made in this well:

1. Without tubing
2. With 3 1/2” Tubing

Interval of interest covers 7” and 9-5/8” casings
Case Study #9 – Corrosion Evaluation Comparison

Run 1 – 2P without tubing

Run 2 – 3P with 3-1/2” tubing
Thru’ Tubing – Tubing Eccentricity & Casing Deformation

Unfocused low magnetic flux beam

Focused and concentrated high magnetic flux beam

Magnetic Field Distribution of casing deformation

Magnetic Field Distribution of tubing eccentricity
Deformation Monitoring - Concept to Realization

1st Pipe OD: 5"
2nd Pipe OD: 13.3/8"
2nd Pipe Offset: 1.8"

\[ E_{cc} = \frac{\Delta d}{|IR_{2nd} - OR_{1st}|} \]

*IR: Inner Radius
OR: Outer Radius

Eccentricity Ratio Ecc 0 is concentric and 1 is casing touching with tubing
Eccentricity gradually changes during the test as the inner casing and tool are vertically repositioned at 5 mm increments inside the outer casing. Deformation response of the outer casing remains at zero.
SIT testing - 7” Deformed Casing thru’ 5” CRS tubing

Features on Casing are separated as tubing eccentricity and casing deformation.

7” Casing ID
DEC 7” Casing through 3.5” Non-mag Tubing
Case Study #10 – Deformation & Eccentricity

- Tectonically active region
- 15% H2S gas reservoir below salt formation
- Salt creep is a major challenge
- Casing damage accelerated by 2008 magnitude-8 earthquake
- 50+ wells in the field
Case Study #10 – Deformation & Eccentricity

<table>
<thead>
<tr>
<th>Original 7” Casing MFC Log</th>
<th>MTD RAW</th>
</tr>
</thead>
</table>

### Deformation & Eccentricity Data

#### 2018 MFC/MTD Log Data

- **Original Casing**
  - MFC Log
  - Collar

#### 2019/8 DEC Log Data Through Tubing

<table>
<thead>
<tr>
<th>Sensor RAW</th>
<th>SensorC RAW</th>
<th>Eccentricity</th>
<th>Deformation</th>
<th>Azimuthal Loss</th>
<th>Inclination/Rotation</th>
<th>Min/Max Distance</th>
<th>Deformation Ratio</th>
<th>Ecc Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>0</td>
<td>0.5</td>
<td>-0.5</td>
<td>0.5</td>
<td>-0.5</td>
<td>0.5</td>
<td>-0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Deformation Ratio:**

- **Short Axis**
- **Long Axis**

**Ecc Ratio:**

- **Center to Center Distance**
- **Casing Radius**

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### Graphs

- Casing Deformation
- Collar
- New Deformation

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19% of wells worldwide are shut in due to well integrity issues. This adds up to $1 BILLION A DAY of lost revenue.\(^3\)

38% of wells globally are affected by integrity issues.\(^2\)

45% of wells in the Gulf of Mexico have integrity issues.\(^3\)

34% of wells in the North Sea, UK have integrity issues.\(^4\)

18% of wells in the North Sea, Norway have integrity issues.\(^5\)


https://www.landmark.solutions/Portals/o/LMSDocs/Infographics/Well-Integrity-Infographic-1.pdf
Summary

- Pulsed Eddy Current EM casing inspection:
  - Multiple barrier casing inspection
  - Thru-tubing Casing Break / damage
  - Casing Corrosion
  - Old wells with lack of casing information
  - Use as part of a pre-abandonment risk evaluation (P&A)

- Focused Magnetic Imaging for:
  - Monitor casing deformation (time lapse)
  - Locate centralized pipes in proposed abandonment interval during P & A operations
  - Increase PEC thickness accuracy
  - Locate fiber-optics cable clamps/control lines
  - Orientation of dual tubing completions
Questions?