AccuTrak™ Passive Magnetic Ranging Service

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SPE/IADC-173135-MS
High Speed, Continuous Single Well Magnetic Ranging

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PRESENTATION OVERVIEW

- Problem Description
- Implementation Considerations
- Solution Method
- Accuracy Assessment
- Field Testing
PROBLEM DESCRIPTION

\[
B_c^{NED} = \frac{1}{4\pi} \int_{z_{t0}}^{z_{tf}} \frac{\rho(z_t)}{||r_{rel}(z_t)||^3} r_{rel}^{NED}(z_t) \, dz_t
\]

Drill collar

Magnetometer

Target Casing

Residual magnetism

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IMPLEMENTATION CONSIDERATIONS: Casing Residual Magnetism

(a) Idealized Residual Magnetism Distribution

(b) Measured Residual Magnetism Distribution

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IMPLEMENTATION CONSIDERATIONS: Casing Residual Magnetism

Total Magnetic Charge per Joint of Casing:

\[ m_t = \int_0^L |\rho(z)| \, dz \]
IMPLEMENTATION CONSIDERATIONS: Other Uncertainties

Sensing and Reference Field:

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Magnetometer</th>
<th>Earth</th>
<th>Earth</th>
<th>Axial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias</td>
<td>Mag. Field Intensity</td>
<td>Mag. Field Uncertainty</td>
<td>Magnetic Interference</td>
</tr>
<tr>
<td>Standard Deviation or Magnitude</td>
<td>70 nT</td>
<td>50,000</td>
<td>130 nT</td>
<td>150 nT</td>
</tr>
<tr>
<td></td>
<td>0.0016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 mrad</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Orientation and BUR:

\[
\frac{d r_{mag}^{NED}}{dz} = (T_{NED}^W)^T u_3
\]

\[
\frac{dT_{NED}^W}{dz} = \begin{cases} 
- [(\omega_{slide}^W + \delta \omega_{slide}^W) \times T_{NED}^W] & \text{while sliding} \\
\delta \omega_{rot}^W & \text{while rotating}
\end{cases}
\]
SOLUTION DESCRIPTION

B_total

Assumed Trajectory

True Trajectory

Update
SOLUTION DESCRIPTION: Operational Implementation

Casing Residual Magnetism Info.

Surface Software

Mud Pulse Telemetry

Downhole Measurements from Directional Sub

Ranging Display

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RANGING DISPLAY
ACCURACY ASSESSMENT

Simulation Results:
• Two horizontal wells
• Displaced vertically by 5 meters
• Monte Carlo simulation

<table>
<thead>
<tr>
<th>Method of Providing Total Magnetic Charge Info. to Ranging SW</th>
<th>Range Uncertainty (2-σ) Divided by Range</th>
<th>Lateral Pos. Uncertainty (2-σ) Divided by Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Ballpark” Average Provided</td>
<td>0.13</td>
<td>0.10</td>
</tr>
<tr>
<td>Simulated Wireline Run</td>
<td>0.09</td>
<td>0.10</td>
</tr>
</tbody>
</table>
FIELD TESTING: Above Ground, 3 m Sep. (1 of 2)

Max. Range Error = 7.55 m
Max. Up/Down Error = 5.29 m

Initial Guess

Actual Well Path
FIELD TESTING: Above Ground, 3 m Sep. (2 of 2)

Max. Range Error = 0.56 m
Max. Up/Down Error = 0.56 m

Final Estimate

Actual Well Path
FIELD TESTING: Above Ground, 5 m Sep. (1 of 2)

Max. Range Error = 5.41 m
Max. Up/Down Error = 5.29 m

Initial Guess

Actual Well Path
FIELD TESTING: Above Ground, 5 m Sep. (2 of 2)
FIELD TESTING: Drilling a Vertical Well (1 of 3)
FIELD TESTING: Drilling a Vertical Well (2 of 3)

Near-Field (< 6 m)
Range Accuracy:

Far-Field (> 6 m)
Range Accuracy:

95% Boundary is ±0.13

95% Boundary is ±0.09
FIELD TESTING: Drilling a Vertical Well (3 of 3)

Near-Field (< 6 m)
Lateral Pos. Accuracy:

Far-Field (> 6 m)
Lateral Pos. Accuracy:
FIELD TESTING:
Weak Signal Capability

• At the BETA test facility, we have successfully demonstrated ranging against a very weak magnetic anomaly.

• This test demonstrated ranging capability initializing at 18m range, and successfully navigated with 10% accuracy out to 25m.
FIELD TESTING: MAD Pass through a SAGD Injector Well

AccuTrak PMR vs. Active ranging "shots"

AccuTrak Real-Time Bit Position

AccuTrak Survey Position