Flow Detection Behind Casing and Formation Pressure Measurement

Aberdeen Formation Evaluation Seminar
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Mohammad Abshenas
TGT Oilfield Services UK
Agenda

- Spectral Noise Logging
- Flow Surveillance Behind Casing
- Formation Pressure in Multi-Layered Reservoirs
- Summary
Formation Pressure in Production Wells

- Formation Pressure in multi-layered reservoirs
  - Openhole Formation Testers
  - Downhole Gauges and PLTs

- Vertical Communication between reservoir units through Flow behind casings.

Formation pressure in reservoirs, and specially in multi-layered development fields is one of the most important parameters for production optimization and filed development plans. Traditionally the pressure of different layers is measured using wireline formation testers during Openhole phase but when it comes to production phase it is not as easy anymore. **Downhole pressure gauges and PLTs only measure an equilibrium pressure or average pressure of multiple layers.**

Cross flows and communication behind casing can make matters much more complex. (picture) as you see all of our measurements will be done inside the wellbore but quite often a lot is happening behind the casing.

Spectral Noise Logging methodology addresses this issue.
Spectral Noise Logging

- Downhole Logging Tool
- Records high resolution noise
- Two measurable parameters: **Frequency** and **Intensity**
- Provides information on reservoir flow *behind multiple barriers*

### Spectral Noise Logging Tool

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Tool OD</td>
<td>1 11/16” (42mm)</td>
</tr>
<tr>
<td>Temp Rating</td>
<td>302 degF (150 C)</td>
</tr>
<tr>
<td>Press Rating</td>
<td>9,000 PSI (60 MPa)</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>8-60,000 Hz</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>90 dB</td>
</tr>
<tr>
<td>Depth of Investigation</td>
<td>10-15 ft.</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>1 sec</td>
</tr>
<tr>
<td>Battery Life</td>
<td>67 hrs</td>
</tr>
<tr>
<td>H2S Resistance</td>
<td>Up to 25%</td>
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</table>
Spectral Noise Logging

<table>
<thead>
<tr>
<th>DEPTH m</th>
<th>WELL SKETCH</th>
<th>LITHOLOGY</th>
<th>PERMEABILITY mD 1000</th>
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<tbody>
<tr>
<td>X340</td>
<td></td>
<td></td>
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<tr>
<td>X350</td>
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<td>X360</td>
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<tr>
<td>X370</td>
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</table>

Noise Spectrum
Spectral Noise Logging
Borehole noise

Borehole flow and perforations generate very low frequency noise
Channels/Faults

Flow in Cement Channels generate slightly higher frequency noise
Matrix flow

Flow in Reservoir Matrix generate higher frequency noise: The tighter the flow path the higher the Frequency
Tight formations

Flow in Tight Reservoir Matrix generate higher frequency noise: The tighter the flow path the higher the Frequency.
Spectral Noise - Analysis
Spectral Noise Logging

- Flow behind casings
- Formation Pressure
- Reservoir Properties such as Permeability, Formation Compressibility
- True Reservoir Height
- Leak Detection and annulus pressure investigation
In this case study, PLT Spinner shows in flow of both water and hydrocarbon from the perforations at A2, but the Noise response reveals a channelling flow behind the casing from A4 which is the actual source of water.
McKinley Theory (1994): Noise Power is directly proportional to $Q \cdot \Delta P$.

Flow rate is also a function of $\Delta P$, by using the ratios of Noise Power ($N$) the true formation pressure is determined.
Reservoir Pressure (SPE-177620)

\[ p(r,t) = p_e + \frac{QB}{4\pi\sigma} \left[ Ei\left( -\frac{r^2}{4\chi t} \right) - 2S \right]; \quad \chi = \frac{k}{\mu \Phi c_t}; \quad \sigma = \frac{kh}{\mu}. \]
In this case study formation pressure of 3 zones is determined by Noise Logging, including 2 zones behind the casing (cross flow), this data was then compared with existing Openhole data with great accuracy.
Reservoir Pressure (SPE-177620)

Comparison of the results from SNL with Pressures from Open Hole Formation Tester

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
<th>Formation pressure</th>
<th>Average values</th>
<th>OH FT</th>
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<tbody>
<tr>
<td>ft</td>
<td>ft</td>
<td>psi</td>
<td>psi</td>
<td>psi</td>
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<tr>
<td>9,461</td>
<td>9,500</td>
<td>3,588.3 – 3,607.7</td>
<td>3,598.0</td>
<td>3,611</td>
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<tr>
<td>9,518</td>
<td>9,555</td>
<td>3,607.8 – 3,626.2</td>
<td>3,617.0</td>
<td>3,648</td>
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<tr>
<td>9,641</td>
<td>9,675</td>
<td>3,651.8 – 3,668.8</td>
<td>3,660.3</td>
<td>Not tested</td>
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<tr>
<td>9,805</td>
<td>9,816</td>
<td>3,758.0 – 3,763.4</td>
<td>3,760.7</td>
<td>Not tested</td>
</tr>
</tbody>
</table>
Summary

- Spectral Noise Logging
- Flow Surveillance behind barriers
- Formation Pressure
- Other Application:
  - Reservoir Permeability, formation Compressibility
  - Well Integrity – Leak Detection, Annulus Pressure Investigation
TGT Oilfield Services UK LTD
WWW.tgtoil.com

KMD Building, Wellington Circle, Altens,
Aberdeen, AB12 3JG
Mohammad.Abshenas@tgtoil.com