Employing acoustic impedance properties and flexural wave imaging in annular material characterization

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Abandonment for eternity – Decisions & Challenges

• Is there sufficient length of good cemented interval
• Are there any formation squeeze intervals to be considered as barrier
• Where is the freepipe and also barite/solids sag zones to plan for casing retrieval
• Is there any gas or gaseous material behind that can pose hazard
• Where do we perform cement repair (PWC), how to verify the cement post PWC
• Can we perform cement evaluation through-tubing
“Share few case examples from ongoing P&A projects in North Sea where acoustic impedance and flexural wave imaging improved characterization of annular material resulting in operators taking more informed decision on annular barrier, pre and post remedial PWC and finally on the optimization of casing cut and retrieval operation”
Ultrasonic and Annulus Characterization Physics

- Pulse-echo acoustic impedance (AI)
- Flexural attenuation
- Third interface Echo (TIE)

Contact between 7 and 9 5/8 in. casings
Ultrasonic and Annulus Characterization Physics

• Measurements
  • Acoustic impedance
  • Flexural attenuation
  • Third Interface
Ultrasonic and Annulus Characterization Physics

• Measurements
  • Acoustic impedance
  • Flexural attenuation
  • Third Interface

• Applications
  • Low-impedance cements
  • Barite sag evaluation
  • Pipe-pipe positioning
  • Complex annular material
  • Annulus velocity imaging
  • Casing cut/pull
Light-Weight Cement Evaluation

1. Acoustic impedance shows poor cement quality
2. Flexural attenuation shows the change in attenuation clearly
3. Flexalone interpretation clearly marks the TOC

10” Casing
0.75” thickness
Understanding the geometry of the annulus

- What are our assumptions on pipe standoff?
- How do we take this into account for P&A decisions?
- Can we measure the standoff?

Based on pipe-pipe contact, drag coefficient can be computed; function of depth, contact length, contact surface area
Casing Retrieval

Before Logging

60 mV 0  Ac  Ac Imp Imp -1 Mrayl 4
CBL  Pulse-Echo

Before Logging

60 mV 0  Ac  Ac Imp Imp -1 Mrayl 4
CBL  Pulse-Echo

Casing Retrieval
Casing Retrieval

Before Logging

After Logging

60 mV 0 Ac Imp Ac Imp -1 Mrayl 4 Flexural 20 dB/m 100

CBL

Pulse-Echo

Flexural Imager

1000 m/s 2000
Casing Retrieval

<table>
<thead>
<tr>
<th>Before Logging</th>
<th>After Logging</th>
<th>60 mV</th>
<th>Ac Imp</th>
<th>Ac Imp</th>
<th>-1 Mrayl</th>
<th>Flexural</th>
<th>20 cm/m</th>
<th>100</th>
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~800m
Casing Retrieval

Casing to be retrieved 9-5/8
Outer casing 13-3/8
Depth ~6000ft, 40deg
Casing Retrieval
Complex Annular Evaluation

10-3/4” casing
0.75” thickness
TIE Xplots to measure annulus velocity

1808.8m $\rightarrow$ 1040 m/s

2254m $\rightarrow$ 694 m/s
Is “anomalously” low annulus velocity indicative of a potential hazard?
Sound Speed in Liquid-Gas Mixtures: Water-Air and Water-Steam

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The sound speed of a two-phase fluid, such as a magma-gas, water-air, or water-steam mixture, is dramatically different from the sound speed of either pure component. In numerous geologic situations the sound speed of such two-phase systems may be of interest: in the search for magma reservoirs, in seismic exploration of geothermal areas, in prediction of P wave velocity decreases prior to earthquakes, and in inversion of crustal and upper mantle seismic records. Probably most dramatically, fluid flow characteristics during eruptions of volcanoes and geysers are strongly dependent on the sound speed of erupting two-phase (or multiphase) fluids. In this paper the sound speeds of water, air, steam, water-air mixtures, and water-steam mixtures are calculated. It is demonstrated that sound speeds calculated from classical acoustic and fluid dynamics analyses agree with results obtained from finite amplitude "waves."
## TIE Annulus Velocities

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<th>Velocity (m/s)</th>
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<td>2332.0</td>
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- Based on the arrival time of the third interface echo signal from the outer casing, the annulus velocity can be determined.
- The annulus velocity output is a very powerful measurement to determine the type of annulus material.

### Velocity
- Water or WBM is around ~ 1500m/s
- Oil and OBM is usually between 900 to 1300m/s
- Degraded oil or emulsion or gas dissolved can pull the velocity below 800m/s
- The exact velocity depends on the chemical composition and temperature

- The data was analysed using slider plot at few select intervals to compute the velocity.
PWC Technique

- Ability to wash through large-diameter perforations and remove any debris in the annulus

- High-velocity, irregularly angled nozzles wash over

- Washing with spacer and spraying cement
How to determine best PWC interval

- TIE measurement to confirm the position of casing within openhole
- Pickup interval for PWC with no formation collapse and well centered casing position

9-5/8, 47# casing
80 deg deviation
Before/After PWC across no cemented interval

- Comparison of Before/After PWC log across non cemented section
- Good match between both logs
- No change in annulus conditions

9-5/8, 47# casing
80 deg deviation
Before/After PWC across cemented interval

- PWC interval 15,319-15,452 ft
- Before/After log compared
- Increase in Acoustic impedance
- Increase in Flexural attenuation
- Decrease in CBL
- VDL highly attenuated

9-5/8, 47# casing
80 deg deviation
What is the challenge in PWC log evaluation?

- Perforation SPF and hole size affect the measurements
- The perforation area is ~3-4% of casing surface area
- Can we remove the affected data and reconstruct the images?
Answer lies in Geology Image log Processing

Inpainting

Filtersim
Processing PWC Cement Log Images
Processing PWC Cement Log Images
Summary

• With wells to be abandoned historical information is quite often lacking
  • Expect the unexpected – solids and fluid behavior

• **Role of measurements** in P&A leading to barrier installation is **critical**. Leveraging the portfolio of measurements available in the industry helps
  • Improve efficiency of operations
  • Anticipate hazards and enable safe operations

• Abandonment for eternity requires a **heightened level of reliability on barrier placement and verification**
Thank You!

The acoustic impedance and flexural wave imaging & third interface echo measurements are rich in information and provide more clarity on the annulus material – critical for abandonment decision making.