Reservoir Surveillance, Wellbore Integrity Evaluation to drive increased production in Mature Fields

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Wireline & Perforating
Mature Fields

Mature fields pose numerous challenges:
- Production decline
- Unwanted water and sand production
- Scale accumulation

Identifying these challenges and root causes through proper monitoring, diagnosis allows for mitigation and intervention.

An integrated data acquisition workflow approach using multiple sensors will yield a comprehensive diagnosis.
SCHEMATIC OF THE CHALLENGE

Water

Scale

Sand

Corrosion

Rapid Production Decline

Wellbore Integrity
Production Gap

Definition:

Outflow Performance

Inflow Performance

Current

Potential

Qo Gap

Production Rate

Pressure
Water Holdup

- Oil Flow
- Water Flow
- Water Entry
- WOC
Integrated Data Acquisition Workflow

Array Production Logging Tools

Cross Section

Vertical Well
Pulse Neutron Oxygen Activation

High Energy Neutron Generator

Gamma Ray Detector

$\gamma$ (6.13 MeV)

O$_{16}^{}$

N$_{16}^{}$

O$_{16}^{}$

Dynamic Condition

Oxygen Molecule (in water) Activation
Integrated Data Acquisition Workflow

Data QA/QC

PL Analysis (Standard + Array Tool)

Temp vs TVD Analysis

Match?

No

Yes

Status known, Transient/ PSS?

Yes

No

Water Flow Log (PNL) Analysis

Match?

Yes

No

Water Source Detected

Recommend Repeat Survey

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Pulsed Neutron Other Applications

- Saturations: Water, Oil, and Gas
- Reservoir Characteristics
  - Shale volume
  - Porosities
  - Mineralogy
- Bypassed Pay zone
- Reservoir Monitoring for:
  - Secondary Recoveries
  - Water, steam, CO2, nitrogen flood
  - Oil, gas, and water saturations
  - Changing oil, gas, water contacts
Integrated Data Acquisition Workflow

TMD3D™ (Thermal Multigate Decay - 3 Detector) Logging Tool

- Advanced multidetector measurements to determine gas saturation
- Verifies gravel pack integrity via silicon and aluminum activation
- Log thru restrictions as small as 2” ID
- Best technology-solution for through tubing and well Gas evaluation!
Integrated Data Acquisition Workflow

RMT-3D

- New 2 1/8” tool with three 1.4” detectors provides water, oil, and gas saturations, through casing, using three independent measurements
- Reduced wellbore parameters dependency to provide the most accurate saturations and hydrocarbon identification available

- BGO Detectors provides superior and robust Carbon-Oxygen with its high energy resolution and defined spectrum
Integrated Data Acquisition Workflow

Acoustic Conformance Examiner

- Characterized in Halliburton Acoustics Facilities
- Field tested in Alaska for 2 major IOCs
- Currently being ran in US, Saudi, Angola and UK

- OD 1-11/16 in.
- Length: 12 ft
- Weight: 45 lb
- 15,000 psi, 300°F
- Bandwidth: 100Hz to 50kHz
- Sensors: 8 Passive – Hydrophones
Acoustic Conformance Examiner

- Allows for radial pinpointing of flow entry (leak)
- Isolate the locations of Leaks (vertical and radial)
- Identify the types of leak
- Determine the leak flow rate

8 Hydrophones

| Casing | Casing | Tubing | 4 in. | Formation | 8 Hydrophones |
Acoustic Conformance Examiner

![Graph showing acoustic conformance with circles highlighting water and gas areas.](image)
Industry’s Regulation has driven an increased emphasis in well integrity monitoring to protect underground water sources, surface spills and environment in General.

Mature wells, are particularly susceptible to integrity problems

Many factors can affect well’s casing and tubing like hydrogen sulfide (H2S), flowing water, etc.

Minerals, wax and asphaltene deposits can restrict the flow in the well

Integrated Data Acquisition Workflow can be customized for each well to provide a complete picture of casing integrity
Advance Casing and Pipe Integrity Evaluation

- **CAST™ Tool – Ultrasonic Evaluation**
  - uses ultrasonic waveforms to create a 360° image of the casing, while evaluating cement to casing bond
  - Tool can be conveyed with e-coil tubing or tractors in deviated or horizontal wells.
  - Capable to operate in casing sizes of 4” up to 14”

- **Multifinger Caliper (MFC) – High-resolution Internal Corrosion Measurements**
  - Uses dozens of individual gauges (or fingers) to caliper the inside of the casing.
  - Provides a high-precision view of corrosion or buildup within the casing string.
  - By combining the MFC tool with the CAST tool, operators can acquire the same information with two different technologies, ensuring complementing data and accurate results.
Advance Casing and Pipe Integrity Evaluation

- **Magnetic Thickness Tool (MTT) – External Measurement for 3D Image of Casing Integrity**
  - The MTT complements other measurements by providing a thickness measurement of the pipe
  - When combined with the multi-finger tool, it can provide an assessment of internal and external pipe’s corrosion or mechanical deformations.

- **Xaminer™ Electromagnetic Corrosion Tool – Cutting-edge Technology Inspects Corrosion through Multiple Strings**
  - Represents the latest advancements in integrity monitoring technology that can penetrate beyond the first layer of casing and into a second casing.
  - Gives first ever look at corrosion on a production casing without the need of removing the tubing string.
  - Determines metal loss in a third tubular up to 12 in. outer diameter
## Capability Profile

<table>
<thead>
<tr>
<th>Application</th>
<th>CAST</th>
<th>MFC</th>
<th>MTT</th>
<th>Xaminer™ Electromagnetic Corrosion Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Barrier Inspection</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Minimum Restriction for Evaluation</td>
<td>3.9 in.</td>
<td>2.75 in.</td>
<td>2.0 in.</td>
<td>2.0 in.</td>
</tr>
<tr>
<td>Tool Maximum OD</td>
<td>3.125 in.</td>
<td>2.125 in.</td>
<td>1.69 in.</td>
<td>1.69 in.</td>
</tr>
<tr>
<td>Provide Average Thickness of Tubular</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Provide Radial Thickness Measurement</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Provide Circumferential Radii</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Identify Holes or Split Tubular</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Operate in Gas or Air-Filled Wells</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3D Image generated by Halliburton's CASE™ casing evaluation and inspection software
Reservoir Surveillance, Wellbore Integrity Evaluation

- Water Production it's often the causal factor of many challenges like: Scaling, Corrosion, Sand Production, Wellbore Integrity and Production Decline
- Production Gap is the difference between what the well can deliver and what the well is actually producing
  - Inflow is affected by fines migration and conformance (water production)
  - Outflow is affected by tubing ID size, restrictions, etc
  - Proper monitoring, diagnostic and intervention can help close this “Gap”
- It is crucial to understand the right depth in which water comes into the wellbore, complex completions require more advance diagnostic and data acquisition to truly understand the root cause of the problem or the prevention of them.
- Array Production tools can minimize uncertainty of depth in which water enters the borehole independent of well deviation
- Acoustic conformance Xaminer is the only leak detection tool capable of determine leak not only at a well's depth but at a radial distance from the tool, as well as characterizing the fluid type that is leaking
- Halliburton offers a myriad of pipe inspection technologies that can be combined for a proper casing and tubing integrity evaluation and monitoring
- A Customized Integrated Data Acquisition workflow with complementing datasets are critical for an effective well monitoring, diagnostic and intervention to drive increase in hydrocarbon production
Who to Contact, Where to get more information

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THANK YOU