New Technology in Wireline Formation Testing & Sampling

Unique Options To Match Your Specific Needs

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Agenda

• History of sampling in Weatherford Wireline

• Selecting the right tool for the job

• New developments

• Technology Highlights

• Summary
History of Formation Testing and Sampling Services in Weatherford Wireline

- **SFT**
  - pressures & “conventional” sampling only

- **FRT**
  - low cost sampling system, basic pump out formation testing tool

- **MFT**
  - slim hole tester, pressures only

- **RES**
  - full suite of options, configurable to well conditions and client requirements

- **Sampling MFT (2013)**
  - slim (2.4” OD) pump out sampling option, built upon proven MFT platform
Because formation testing is not a one-size-fits-all proposition. **Circumstances vary**

<table>
<thead>
<tr>
<th>Circumstances</th>
<th>Formation Testing Considerations</th>
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<tbody>
<tr>
<td>Exploration project</td>
<td>• High levels of uncertainty</td>
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<td></td>
<td>• Typically require many samples</td>
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<td></td>
<td>• Require advanced downhole analysis</td>
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<td>Developed field</td>
<td>• Basic, efficient low-cost FT solution generally appropriate</td>
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<td>High-risk wellbore</td>
<td>• Elevated lost-in-hole risk</td>
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<td>• Prevalence of small clearances and hole problems</td>
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<td>WFT Tools</td>
<td>Operating Conditions</td>
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<td>Reservoir Evaluation System (RES)</td>
<td>• exploration wells&lt;br&gt;• high-profile wells&lt;br&gt;• technically challenging sampling conditions&lt;br&gt;• critical fluids near bubble point&lt;br&gt;• presence of asphaltenes&lt;br&gt;• oil-based muds&lt;br&gt;• carbonate reservoirs</td>
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<td>FRT MFT MFT – sampler (2013)</td>
<td>• lower-cost, development wells</td>
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<td>MFT MFT – memory MFT – sampler (2013)</td>
<td>• hole problems common</td>
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Tech. Focus: FRT (Flow Rate Tester)

A highly cost-effective wireline-deployed formation testing and fluid sampling system

- Basic dual-packers system for zonal isolation or optional OH Probe
- Basic pump-out section for sample cleanup
- WBM Fluid identification (Resistivity Capacitance)
- H₂S rated (less 5%)
- Two PVT samples per run
Tech. Focus: Reservoir Evaluation System (RES)

- Uniform tool OD: 4.5 in

- Sectional design:
  - Pump (RMP)
  - Probe (REP)
  - Packers (RPS)
  - Fluid Measurement (RFM)
  - Optical Fluid Analyzer (RFA)
  - Fluid Sampling (RSC & RSB)
Tech. Focus: Reservoir Evaluation System (RES)

- Multiple features that reduce pressure uncertainty
  - Dual quartz gauges
  - Gauges at same location
  - Customer dedicated gauge option
  - Quick temperature stabilization

- Dual flow lines
  - Increase tool configuration options
  - Reduce uncertainty in focused sample cleanup,
  - Enable back-up of key measurements
  - Reduce tool length / rat hole for focused sampling
RES Measured Pump (RMP)

**Pump Rate (Pressure Differential Dependent):**

- Range: 0.05-0.75 Gallons per Minute
- High rates for fast clean up
- Slow control for heavy oil, unconsolidated sands, critical fluids

**New generation pump**

- Pump piston position measurement
  - Measured rates and volumes
- Direct hydraulic rate control
  - Surface controlled hydraulic servo valve
- Ability to run multiple pumps in same stack
  - More effective flow control while sampling
RMP Application: Spain

- Client pumped for > 24hrs / well on three well campaign, less than would have been required using conventional tools
- Overcame deep invasion to collect representative sample
- Five mini-frac’s performed to determine formation fracture
Packer and Probe Seal Options

**OH Probe (REP):**
- Best-in-class flowline storage of 62 cm³
- Faster build-ups and crisper pressure response
- 60 cm³ recyclable pretest 0.1-5 cm³/s
- Large reservoir testing range from 0.008 mD- 4D
- High articulation seals more reliably
- Focus sampling options to expedite clean samples

**Straddle Packers:**
- Sizes from 4.5”-14”
- Variable spacing from 0.5-5M
Relevance of Low Tool Storage Volume

- Differences in storage volume *do* affect measurements

- **Example:** Tool leaving tool storage sooner is ~1/2 decade faster to flow regimes
RES Fluid Measurement (RFM)

- Dual sensors, one in each flow line
- Fluid Properties Measurement:
  - Resistivity: 0.001 – 20 ohm-m
  - Dielectric: 1.00 – 70.0
  - Viscosity: 0.5 – 1000 cSt.
  - Fluid Density: 0 – 1.500 g/cc
    - Mechanical: 0.01 g/cc
    - Nuclear (Optional): 0.002 g/cc
RES Fluid Analyzer (RFA)

- 20 Channel Photometer
  - Optimized distribution
- RI based Gas Breakout Sensor

- Optical Reference Path
  - Dynamic Calibration
  - Measurement Repeatability

- Optical Fluid Analysis
  - Oil flag
  - Water flag
  - CO2 flag
  - Methane flag
  - Contamination indicator

- Refractive Index gas breakout flag

RES Fluid Analyzer - Example Spectrums
RES Sample Carrier (RSC)

- Uniform 6 cc dead volume per bottle
- 4 Samples Bottles per carrier (up to 4 carriers – 16 Samples per trip)
- Number of Carriers limited by conveyance
- Integrated exhaust port with valve
- Electro – hydraulic bottle valves
  - Multiple operation possible
  - More than one bottle filling @ time @ single depth
Ensuring Sample Integrity, Across All Platforms

- All sampling systems use same **premium-grade** sample bottle
- Ensures sample integrity, from wellsite to the lab
MFT Compact™ Formation Tester

*A pressure testing workhorse*

- No complicated hydraulic systems
- Unique centralized articulating pad seals more reliably than traditional pad
- Technology leader 9 cm³ tool storage volume
- Variable rate 40 cm³ pretest
- Large logging range from 3.5”-17” wellbores
- More conveyance options than any other formation tester
- 749 jobs in 2011 with only 8 CMS failures
- Only 8 MFT’s have ever been lost in hole since 2003 release
Case Study: MFT Compact™ Formation Tester (Texas, USA)

- Compact™ repeat formation tester performs 53 pressure tests in difficult hole conditions
- Operation completed in less than 8 ½ hours

- Compact™ Formation Sampler compatible with Assure™ Conveyance systems
  - Can obtain samples where traditional larger testers are too costly or risk

- First truly centralized sampler to mitigate differential sticking

- Fully Functional:
  - Resistivity and Capacitance Fluid ID for WBM clean up
  - Downhole pump
  - Three PVT samples per run
  - Proven MFT Probe

- Alternative for LWD samplers where cost is factor
Tech. Highlight: Memory MFT

- Enables formation pressure testing without wireline
  - Draw down rates, volume and build up times programmed prior to descent, based on historical field knowledge
  - Ability to pulse up hole a formation pressure and measurement when requested (example final build up pressure) to assist in data QC
  - Sample clean-up time limited by down hole battery / drawdown (2-8 hrs)

- Alternative to LWD, traditional wireline formation testing when they are too costly, not available or risky

![Standpipe Pressure During MFT Pre-Test Routine](chart1)

![Airfield Pipe - 12 Bit Analysis](chart2)

On many occasions it may only be necessary to wait for the first few pulses in order to make the decision on what to do next. Tight tests can be seen early and therefore the MFT can be moved to the next point.
Summary

- Multiple formation testing options to enable tailored solutions

- Several designed to minimize risk, even in complex wells

- New technologies coming soon

- Track record of successful jobs that span the globe
Full Support!