

## LOGIQ® WaveSonic® Service

Halliburton's Third-Generation, Ultra-Reliable, Crossed-Dipole Sonic Tool

Halliburton's LOGIQ® WaveSonic® crossed-dipole sonic tool makes it easy to determine fast and slow shear-wave travel times and their orientation in the formation. With the WaveSonic service, you can even calculate minimum and maximum principal stresses and stress field orientation by combining oriented slowness data with overburden and pore-pressure data. This information is vital for geomechanical analysis, wellbore stability, and production enhancement-treatment design.

Sonic anisotropy and the orientation of the anisotropy can be used to determine the orientation of natural fractures. Sonic attributes such as P-wave slowness, fast and slow shear-wave travel time, identification of compressive fluids in the pore space, and anisotropy orientation allow for better 3D seismic analysis.

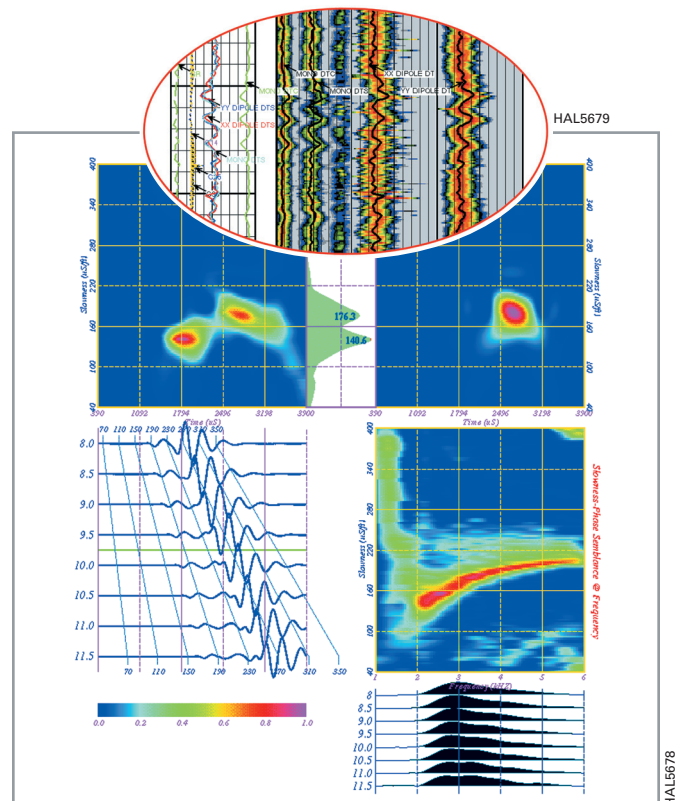
### The Product of Superior Technology

Halliburton's LOGIQ WaveSonic service provides simultaneous monopole and crossed-dipole sonic information. P-wave and S-wave slowness can be obtained in formation conditions ranging from poorly consolidated high-porosity gas-saturated sandstones to low-porosity carbonates. The flexural wave energy is propagated from a low-frequency, on-depth, crossed-dipole bender-bar source. The low-frequency flexural wave travels at the true shear slowness of the formation. A low-frequency monopole source is utilized, so the P-wave and flexural-wave data have similar depths of investigations well beyond any near-wellbore alteration.

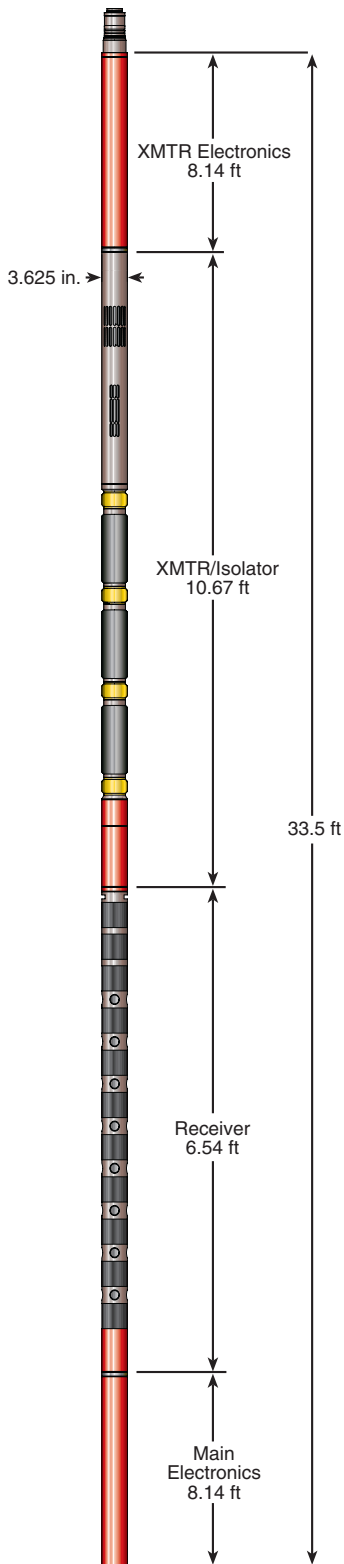
### Benefits

- Low-frequency monopole and dipole sources for deeper investigations of sonic slowness measurements beyond any near-wellbore alteration effects
- Broadband 8-level, quad-receiver array for high-quality waveform data; all 96 waveforms for each set of transmitter firings are recorded at the surface for advanced waveform processing techniques
- Can be combined with all LOGIQ openhole tools

- On-depth, low-frequency bender-bar source provides a clean source signal:
  - No need for dispersion corrections for slowness determination
  - No depth shifting of waveform data for anisotropy analysis
- Drillpipe-conveyed operations are possible due to the strength of the isolator design.



*This is an example of a semblance diagnostic plot of the waveform data from the eight waveforms. In the circle is a section of a log showing monopole P-wave slowness and semblance quality, monopole refracted shear-wave slowness and semblance quality, X-X dipole slowness and semblance quality, and Y-Y dipole slowness and semblance quality.*



| WaveSonic Service Specifications  |   |                       |        |
|-----------------------------------|---|-----------------------|--------|
| <b>Dimensions and Ratings</b>     |   |                       |        |
| Maximum Temperature               | 350°F (177°C)   |                       |        |
| Maximum OD                        | 3.625 in. (92.1 mm)   |                       |        |
| Maximum Pressure                  | 20,000 psi (138 MPa)  |                       |        |
| Minimum Hole                      | 4.5 in. (114.3 mm)  |                       |        |
| Maximum Hole                      | 16.0 in. (406.4 mm)*  |                       |        |
| Make Up Length                    | 34 ft (7.3 m)   |                       |        |
| Weight                            | 520 lb (236 kg)   |                       |        |
| <b>Borehole Conditions</b>        |   |                       |        |
| Borehole Fluids                   | Saltwater, Freshwater, Oil  |                       |        |
| Recommended Maximum Logging Speed | 30 ft/min (9.1 m/min)<br>simultaneous monopole and crossed dipole 2 samples per foot                                  |                       |        |
| Tool Positioning                  | Centralized   |                       |        |
| <b>Hardware Characteristics</b>   |   |                       |        |
| Source Type                       | Piezoelectric Monopole<br>On-Depth Bender-Bar X-X and Y-Y Dipole  |                       |        |
| Sensor Spacings                   | 0.5 ft (15 cm) between receivers<br>Dipole 9.2 ft (2.8 m) to 1st receiver<br>Monopole 10.2 ft (3.1 m) to 1st receiver |                       |        |
| Firing Rate                       | Variable (Software Controlled)  |                       |        |
| Digitizing Interval               | Programmable  |                       |        |
| Samples per Sensor                | Programmable  |                       |        |
| Source Characteristic             | Dipole 500 Hz to 3 kHz-programmable<br>Monopole center frequency 5 to 6 kHz, 1 kHz to 12 kHz bandwidth                |                       |        |
| Measurement Bandwidth             | 500 Hz to 20 kHz  |                       |        |
| Combinability                     | All LOGIQ® tools  |                       |        |
| Build Rate/Dog-Leg-Severity       | 20° per 100 ft (20° per 30 m) without flex joints   |                       |        |
| <b>Measurement</b>                |   |                       |        |
| Principle                         | Time-slowness $\Delta t_c$ , $\Delta t_{sxx}$ , and $\Delta t_{syy}$  |                       |        |
| Range                             | Dynamic   |                       |        |
| Vertical Resolution               | 6 in. (15 cm)   |                       |        |
| Depth of Investigation            | 3 ft to 20 ft (0.9 m to 6.1 m)  |                       |        |
| Resolution                        | 0.2 $\mu$ s   |                       |        |
| Primary Curves                    | $\Delta t_c$ , $\Delta t_{syy}$ , and $\Delta t_{sxx}$  |                       |        |
| Secondary Curves                  | VPVS, $\phi_c$ , ITTp, ITTs semblance quality, slowness anisotropy,<br>Poisson's ratio, Stoneley slowness             |                       |        |
| <b>Calibration</b>                |   |                       |        |
| Primary                           | Internal check  |                       |        |
| Secondary                         | Sonde simulator   |                       |        |
| Wellsite Verifier                 | Casing for 57 $\mu$ s/ft $\Delta t_c$ check   |                       |        |
| <b>Physical Strengths**</b>       |   |                       |        |
| Hardware                          | Tension   | Compression           | Torque |
| Tool Joints                       | 100,000 lb (444 kN.m)   | 100,000 lb (444 kN.m) | N/A    |
| Isolator                          | 100,000 lb (444 kN.m)   | 100,000 lb (444 kN.m) | N/A    |

\* 20 in. (500 mm) for monopole data with eccentered tool    \*\* Strengths apply to new tools at 70°F (21°C) and 0 psi (0 MPa)