Schlumberger

ThruBit

Through-the-bit logging services slim multiconveyance formation evaluation tools

APPLICATIONS

THRUBIT SERVICES QUAD-COMBO

- Log acquisition in slim holes, highly deviated and horizontal wells, and unconventional plays
- Log acquisition in difficult or unstable boreholes (tortuous, rugose, loss zones, or severe washouts)
- Reservoir delineation
- Definition of facies and depositional environments
- Igneous and source rock recognition
- Reservoir quality and completion quality for completion optimization in unconventional reservoirs

THRUBIT HRLA HIGH-RESOLUTION LATEROLOG ARRAY TOOL

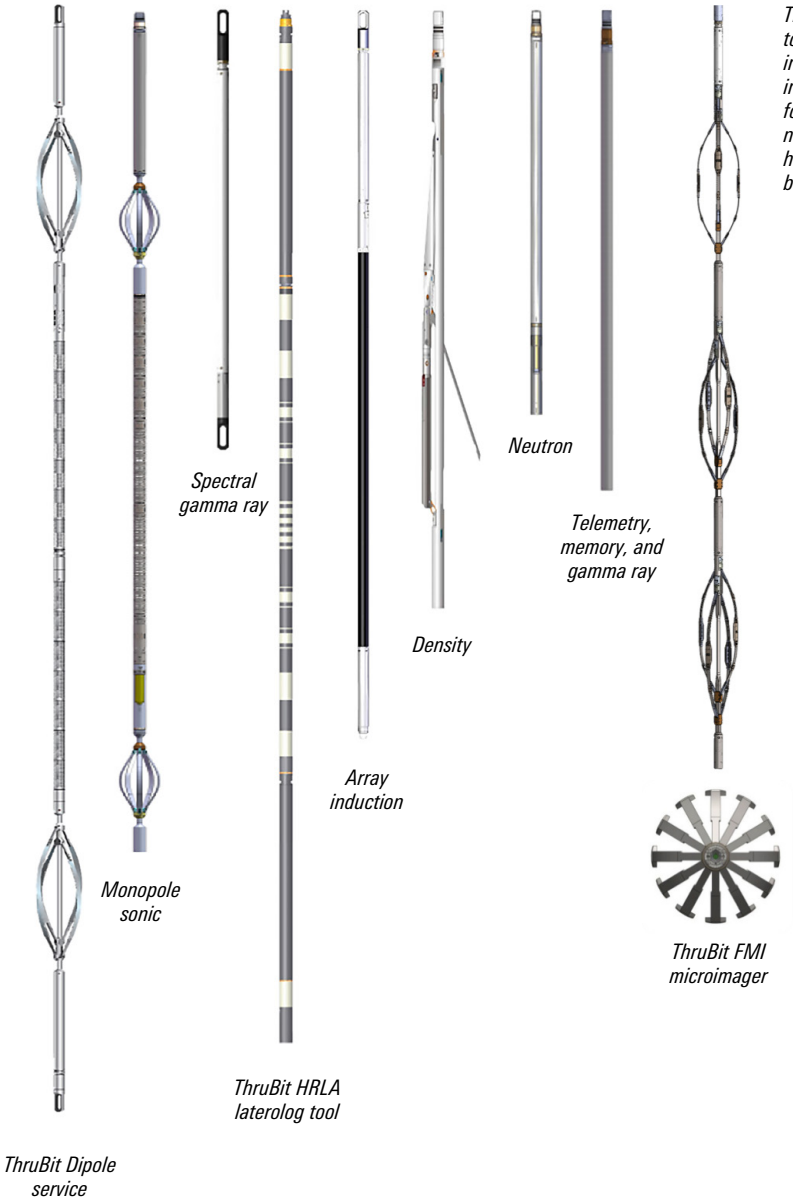
- Reservoir characterization workflow in unconventional plays
- Evaluation in slim, highly deviated and horizontal wells
- Well placement, completion, and hydraulic fracturing optimization
- Invasion characterization for permeability indication
- Thin-bed detection and evaluation
- Resistivity determination in conductive mud systems
- Water saturation determination
- Identification of fluid contacts

THRUBIT DIPOLE THROUGH-THE-BIT ACOUSTIC SERVICE

- Petrophysics
  - Porosity estimation
  - Lithology and clay identification
  - Gas identification
- Stoneley wave measurement
  - Fracture evaluation
  - Permeability and mobility
- Geomechanics
  - Engineered design of hydraulic fracturing
  - Guidance for selective perforating and sand control

The slim multiconveyance formation evaluation tools of ThruBit* through-the-bit logging services provide a complete portfolio of logging measurements packaged in small-diameter 2⅛-in tools. The measurements range from the classic triple- and quad-combo suites through advanced measurements of high-resolution laterolog, spectral gamma ray, dipole sonic, and borehole imaging.

The 2⅛-in diameter of ThruBit services tools enables deployment in almost all common borehole sizes. The slim design also makes it possible to deploy the entire logging suite using ThruBit services conveyance through most drillpipe sizes, jars, and collars before passing through the coordinating Portal* pass-through bit. The ThruBit services tools can be run as standard real-time wireline services or in memory mode using the unique ThruBit services conveyance technique.



ThruBit services tools can be run in combination or individually to meet formation evaluation needs in slim holes and difficult borehole conditions.

  - Well placement and stability evaluation based on stress regime identification and pore pressure determination
- Geophysics
  - Velocity calibration and time-depth conversion
  - Improved 3D seismic analysis and seismic tie-ins
  - Synthetic seismograms
  - Identification of formation heterogeneity through anisotropy detection

THRUBIT FMI THROUGH-THE-BIT MICROIMAGER

- Reservoir characterization workflow in unconventional plays
- Evaluation of slim highly deviated and horizontal wells
- Fractured reservoir characterization and modeling
- Evaluation of structural geology and sedimentary features, rock texture analysis, and geomechanics answers
- Well placement, completion, and hydraulic fracturing optimization
- Secondary porosity evaluation
- Thin-bed detection and evaluation

The ThruBit services tools provide further deployment flexibility as individual components:

- **Telemetry, memory, and gamma ray device** provides communication and memory functions for the entire logging string. The gamma ray detector measures naturally occurring gamma rays in the formation, which are used for correlation and qualitative evaluation of clay content. The multiaxis accelerometer monitors tool orientation, motion, and vibration. Borehole inclination and temperature are also measured.
- **Triple-combo suite** comprises neutron, density, and induction resistivity in combination with the telemetry, memory, and gamma ray device.
- **Neutron tool** operates in both openhole and cased hole environments to obtain thermal neutron porosity measurements. The measurements and borehole and environmental corrections that can be applied are similar to those for the classic neutron porosity (NPHI) and thermal neutron porosity (TNPH) tools.
- **Density tool** measures formation bulk density, photoelectric factor, and borehole size. The tool's scintillation detectors are housed in an articulated pad for better contact with the borehole wall, which helps maintain measurement quality in deviated and rugose holes. The single-arm caliper also contributes to applying the tool against the formation while it measures the hole size. Raw measurement processing includes a correction algorithm that preserves overall density accuracy over a wide range of borehole sizes, mud types, and mud weights.
- **Array induction tool** has five median depths of investigation and three vertical resolutions. The incorporated mud resistivity sensor provides critical data for making corrections and analyzing borehole fluids.
- **ThruBit HRLA* high-resolution laterolog array tool** measures resistivity at multiple depths of investigation with focused arrays. By taking an array of measurements, it is possible to solve a formation model to determine and correct for environmental effects (such as shoulder bed effects and invasion) and calculate the uninvaded formation resistivity R_t.
- **Waveform sonic tool** uses a single monopole transmitter in conjunction with a single receiver spaced 36 in from the transmitter and a group of six receivers spaced 6 in apart starting at 60 in from the transmitter. The waveforms recorded at the receivers undergo slowness-time-coherence (STC) processing to obtain compressional and shear velocities. The waveform sonic tool is run centralized in the ThruBit services toolstring by employing a pair inline centralizers.
- **Spectral gamma ray suite** measures the total gamma ray spectra for resolution into potassium, thorium, and uranium. These three most common components of naturally occurring radiation in sands and shales are used to distinguish features, determine clay type, identify radioactivity in sands, and help in determining total organic carbon (TOC), an important characteristic for the evaluation of unconventional reservoirs.
- **ThruBit Dipole* through-the-bit acoustic service** obtains both monopole and cross-dipole waveforms along with Stoneley wave acquisition. A 3D anisotropy algorithm transforms the compressional, fast and slow shear, and Stoneley slowness measurements with respect to the borehole axes. The resulting referenced anisotropic moduli are used to classify the formation as isotropic or anisotropic and determine whether the anisotropy is intrinsic or caused by drilling-induced stress. This information is critical for guiding well completion, designing fracturing stages, understanding wellbore stability aspects, and planning trajectories for future wells.
- **ThruBit FMI* through-the-bit formation microimager** acquires high-resolution image and dip data along with measuring two axial diameters. With 80% borehole coverage in a 6-in hole and 0.2-in image resolution, the ThruBit FMI microimager provides high-resolution answers for structural, stratigraphic, and geomechanical understanding. The innovative configuration of the pads in the shape of a bow spring helps apply them to the formation face and centralize the microimager along with additional centralizers in the toolstring.

Measurement Specifications

	ThruBit Services Telemetry, Memory, and Gamma Ray	ThruBit Services Neutron	ThruBit Services Density	ThruBit Services Array Induction	ThruBit HRLA High-Resolution Array Laterolog Tool	ThruBit Services Waveform Sonic	ThruBit Services Spectral Gamma Ray	ThruBit Dipole Through-the-Bit Acoustic Service	ThruBit FMI Through-the-Bit Microimager
Output	Formation gamma ray, borehole temperature, inclination, relative bearing	Thermal neutron porosity	Bulk density, photoelectric factor (PEF), single-axis borehole caliper	Five deep induction resisitivities (10, 20, 30, 60, and 90 in), mud resisitivity R_m Optional SP†	Five array resistivities, true resistivity R_t, diameter of invasion, invaded zone resistivity R_{xo}	Monopople compressional and shear slowness, full waveforms	Formation gamma ray; corrected gamma ray for uranium; potassium, thorium, and uranium curves	Monopole compressional, dipole shear, full waveforms, Stoneley permeability	Formation images and dips, two axial diameters
Logging speed	Up to 3,600 ft/h [1,097 m/h]	1,800 ft/h [549 m/h]	1,800 ft/h [549 m/h]	Up to 3,600 ft/h [1,097 m/h]	Up to 3,600 ft/h [1,097 m/h]	Up to 3,600 ft/h [1,097 m/h]	1,800 ft/h [549 m/h]	1,800 ft/h [549 m/h]	1,800 ft/h [549 m/h]
Range of measurement	0 to 1,000 API	0 to 60 pu (0 to 60% uncorrected porosity)	Bulk density: 1.04 to 3.3 g/cm^3 PEF: 0.9 to 10 Caliper: 2.13 to 18 in [5.41 to 45.72 cm]	0.01 to 2,000 ohm.m	0.2 to 100,000 ohm.m at R_m = 1 0.2 to 20,000 ohm.m at R_m = 0.02	42 to 155 us/ft [138 to 508 us/m]	0 to 1,000 API	Standard shear slowness: <200 us/ft [<722 us/m]	Sampling rate: 0.05 in [0.13 cm] Borehole coverage: 80% in 6-in [15.24-cm] hole
Vertical resolution	24 in [60.96 cm]	12 to 15 in [30.48 to 38.1 cm]	Bulk density: 9 to 12 in [22.86 to 30.48 cm]	1, 2, and 4 ft [0.30, 0.61, and 1.22 m]	12 in [30.48 cm]	24 in [60.96 cm]	60 in at 1,800 ft/h [152 cm at 549 m/h] 30 in at 900 ft/h [76 cm at 274 m/h]	<44-in [<112 cm] processing resolution for 6-in [15.24-cm] sampling rate	0.2 in [0.51 cm]
Accuracy	Gamma ray: ±5%	±1 pu for <20 pu ±2 pu for 20 to 30 pu ±6 pu for 30 to 45 pu	Bulk density: ±0.01 g/cm^3 PEF: ±0.15 Caliper: ±0.2 in [±0.51 cm	±1 mmho or ±2% (whichever is greater)	1 to 2,000 ohm.m: ±5% 2,000 to 5,000 ohm.m: ±10 5,000 to 100,000 ohm.m: ±20%	±2 us/ft [±6.6 us/m]	Th: ±3.2 ppm or ±5% of reading U: ±1 ppm or ±5% of reading K: ±0.5 wt% or ±10% of reading	Delta-*t* for <8¾-in [<22.22-cm] hole size: ±2 us/m [±0.61 us/ft] or ±2% (whichever is greater)	Diameter: ±0.2 in [0.51 cm] Deviation: ±0.2° for 5° < deviation < 85°
Depth of investigation	12 in [30.48 cm]	10 in [25.4 cm]	Bulk density: 2 in [5.08 cm] PEF: 2 in [5.08 cm]	10 in [25.40 cm] 20 in [50.80 cm] 30 in [76.20 cm] 60 in [152.40 cm] 90 in [228.60 cm]	50 in [12.7 cm]‡	3 in [7.62 cm]	12 in [30.48 cm]	Delta-*t* compressional: 3 to 6 in Delta-t shear: 3 times the borehole diameter	1 in [2.54 cm]
Mud type or weight limitations	None	None	None	Salt-saturated muds are usually outside the operating range of induction tools	Conductive mud systems only	Aerated and foam muds usually outside operating range of acoustic tools	None	Aerated and foam muds usually outside operating range of acoustic tools	Water-base mud with maximum R_m = 50 ohm.m
Logging environment	Open and cased hole	Open and cased hole	Open and cased hole	Open and cased hole	Open hole	Open and cased hole	Open and cased hole	Open and cased hole	Open hole
Combinability	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools	Fully combinable with all ThruBit services and tools
Acquisition mode	Real time (surface readout) Memory	Real time (surface readout) Memory	Real time (surface readout) Memory	Real time (surface readout) Memory†	Real time (surface readout) Memory	Real time (surface readout) Memory	Real time (status only) Memory	Real time (status only) Memory	Memory mode Memory pumpdown mode

† Spontaneous potential measured by a stand-alone device and only for real-time operation (no memory mode)

‡ Median response at 10:1 contrast of true to invaded zone resistivity

Mechanical Specifications

	ThruBit Services Telemetry, Memory, and Gamma Ray	ThruBit Services Neutron	ThruBit Services Density	ThruBit Services Array Induction	ThruBit HRLA High-Resolution Array Laterolog Tool	ThruBit Services Waveform Sonic	ThruBit Services Spectral Gamma Ray	ThruBit Dipole Through-the-Bit Acoustic Service	ThruBit FMI Through-the-Bit Microimager
Temperature rating	300 degF [150 degC] High-temperature version†: 350 degF [175 degC]	300 degF [150 degC] High-temperature version†: 350 degF [175 degC]	300 degF [150 degC] High-temperature version†: 350 degF [175 degC]	300 degF [150 degC] High-temperature version†: 350 degF [175 degC]	300 degF [150 degC]	300 degF [150 degC]	300 degF [150 degC]	300 degF [150 degC]	300 degF [150 degC]
Pressure rating	15,000 psi [103 MPa]	15,000 psi [103 MPa]	15,000 psi [103 MPa]	15,000 psi [103 MPa]	15,000 psi [103 MPa]	15,000 psi [103 MPa]	15,000 psi [103 MPa]	17,500 psi [120 MPa]	15,000 psi [103 MPa]
Borehole size—min.	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	3 in [7.62 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID	5.5 in [13.97 cm] Through-pipe conveyance: 2.375-in [6.03-cm] min. drift ID
Borehole size—max.	14 in [35.56 cm]	16 in [40.64 cm]	16 in [40.64 cm]	16 in [40.64 cm]	16 in [40.64 cm]	13.25 in [33.66 cm]	14 in [35.56cm]	8.75 in [22.23 cm]	9.75 in [24.77 cm]
Outside diameter	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]	2.125 in [5.4 cm]
Length	6.13 ft [1.87 m]	4.77 ft [1.45 m]	10.48 ft [3.19 m]	15.48 ft [4.72m]	24.08 ft [7.34 m]	19.55 ft [5.96 m]	5.84 ft [1.78m]	29.11 ft [8.87 m]	31.13 ft [9.49 m]
Weight	43 lbm [19.5 kg]	35 lbm [15.88 kg]	106 lbm [42.64 kg]	88 lbm [39.92 kg]	247 lbm [112 kg]	114 lbm [51.7 kg]	38 lbm [17.3 kg]	145 lbm [66 kg]	138 lbm [62.6 kg]
Tension	49,000 lbf [217,963 N]	49,000 lbf [217,963 N]	34,000 lbf [151,240 N]	20,000 lbf [88,964 N]	13,488 lbf [60,000 N]	9,000 lbf [40,033 N]	49,000 lb [217,963 N]	25,000 lbf [111,206 N]	30,000 lbf [133,447 N]
Conveyance options†	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	tandard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (real time) Wireline through pipe (real time) Pumpdown ThruBit services conveyance (memory) Tractor (real time) Coiled tubing (real time or memory) Slickline (memory)	Standard wireline logging (memory) Wireline through pipe (memory) Pumpdown ThruBit services conveyance (memory) Tractor (memory) Coiled tubing (memory) Slickline (memory)

† Contact your Schlumberger representative in advance for equipment planning and job requirements

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