ThruBit logging services

Applications
- Openhole logging in
  - Horizontal and high-angle wells
  - Unconventional plays
  - Unstable boreholes
  - Poor-quality boreholes (washed out, rugose, or tortuous)
- Completion optimization

Benefits
- Reduced time acquiring logs because deployment and acquisition can occur during the conditioning trip
- Minimized risk through tool retrievability and full well control
- Streamlined logistics compared with LWD and drillpipe conveyance

Features
- Industry standard or higher performance from a slimhole tool
- Quad- or triple-combo or individual tools
- Logging toolstring and borehole integrity protected by the presence of pipe
- Wireline and memory mode logging
- Well fluid circulation and pressure control maintenance

The options for acquiring petrophysical logging data in high-angle, horizontal, or unstable wells are no longer limited to the extremes of specialized conveyance or forgoing logging completely. ThruBit* through-the-bit logging services deliver the quad-combo logging suite through the drillstring and Portal* bit to log the open borehole on wireline or as the drillpipe is tripped out of the hole.
ThruBit through-the-bit logging services provide operators with a full wireline measurement suite from the small-diameter quad- or triple-combo toolstring. This unique conveyance platform enables acquiring logs in wells that are difficult to access, including extended-reach wells where the tools can be pumped down. With a diameter of only 2½ in, the entire logging suite is sufficiently slim to pass through the center of most drillpipe, jars, collars, and out the opening of the Portal bit.

The logging suite can be run as individual components or in triple- or quad-combo configuration:

- **Telemetry, memory, and gamma ray device** provides communications and memory functions for the entire logging string. The gamma ray detector measures naturally occurring gamma rays in the formation as a correlation basis and to provide a qualitative evaluation of clay content. The multiaxis accelerometer monitors downhole tool orientation, motion, and vibration. Borehole inclination and temperature are also measured.

- **Array induction tool** has five median depths of investigation and three vertical resolutions. The induction tool also incorporates a mud resistivity sensor for making corrections and analyzing borehole fluids.

- **Neutron tool** operates in both openhole and cased hole environments. It uses a californium (Cf) source to obtain thermal neutron porosity measurements. In addition to borehole temperature and pressure corrections, the neutron porosity measurement can be corrected for environmental factors such as hole size, mud weight, salinity, and tool standoff.

- **Density tool** measures formation bulk density, photoelectric factor (PEF), and borehole size. Raw measurement processing includes a correction algorithm that preserves overall density accuracy across a wide range of borehole sizes, mud types, and mud weights.

The tool’s scintillation detectors are housed in an articulated pad for better contact with the formation, which maintains measurement quality in deviated and rugose holes. A single-arm caliper also helps press the tool against the formation while it measures hole size.

- **Waveform sonic tool** has a monopole transmitter and six-receiver array that records waveforms at each receiver for subsequent slowness-time-coherence (STC) processing to obtain compressional and shear velocities. Monopole shear velocity can be determined from the sonic measurement in formations where the compressional and shear velocities are faster than the acoustic velocity in mud.

- **Spectral gamma ray tool** provides insight into the mineral composition of formations. The total gamma ray spectra measured is resolved into the three most common components of naturally occurring radiation in sands and shales—potassium, thorium, and uranium (K, Th, and U respectively). These data are used to distinguish important features of the clay or sand around the wellbore and help in determining the total organic carbon (TOC) content. The clay type can be determined, and sand can be identified as radioactive.

The wireline connection to the logging toolstring enables the ThruBit services logging engineer to create a downlog and monitor toolstring functionality from the moment the logging tools leave the surface until they are switched to memory mode if logging is conducted as the drillpipe is tripped from the hole.
ThruBit services conveyance

**Portal PDC bit**
The Portal PDC bit design allows the ThruBit services slim logging tools on wireline to pass through a 2½-in center opening in the bit the end of the drillstring. The bit design is adaptable to almost any PDC bit model and is available in diameters of 5¾ in to 12¼ in.

**Hangoff sub**
Positioned above the Portal bit in the drillstring is a hangoff sub, which precisely positions the logging toolstring when it is extended below the bit opening. The sub restricts the movement of a no-go collar near the top of the logging toolstring and prevents it from traveling farther down once the logging sensors are protruding into the open hole.

**Dropoff tool**
If logging in memory mode is required, the logging tools are run into the well on wireline below a dropoff tool. Once the logging tools are positioned on the hangoff sub, the dropoff tool disconnects from the logging tool and the wireline is retrieved.

**Full surface pressure control**
The surface pressure equipment of the ThruBit services enables the driller to rotate the drillstring and also circulate while deploying the logging tools. A float valve can be installed in the BHA as an added control measure as needed. The flapper-style valve allows the logging tools and ancillary equipment to pass through in both directions.

**Operational flexibility:**

**Conventional wireline or drillpipe-conveyed memory mode**
Where conventional wireline operations are not advisable or not possible in vertical or horizontal wells, deployment using ThruBit services provides unparalleled flexibility in logging, both reducing risk and returning high-quality data. Anywhere the Portal bit can reach can be logged.

Prior to logging, the hole may be reamed and conditioned using the Portal bit. The logging suite is then run through the drillstring on wireline. Once the logging suite reaches the end of the drillstring, it is positioned on the hangoff sub so that the logging sensors are passed through the Portal bit and positioned below it, in the open hole. The wireline is disconnected and retrieved, and the logging string is used to log in memory mode as the pipe is tripped out.

In wells where a gravity descent is not possible, the logging toolstring is pumped down to the end of the drillstring and positioned for conducting memory mode logging while tripping out.

In either horizontal or vertical wells, the logging toolstring can be retrieved before the drillpipe is completely returned to surface. Having the drillpipe still in the well can speed the implementation of completion operations.

At all times during the deployment or logging operation, the driller maintains complete control of the drillstring. Circulation and rotation are conducted as needed.

In the case of stuck pipe, the logging tools can be readily retrieved to surface to avoid damage while the pipe is freed.

![Diagram](image)

The hangoff sub assembly, battery, and retrieval tool enable recording logs in memory mode as the pipe is tripped from the well. The logging tools can be retrieved at any time after the wireline is released.

“By deploying ThruBit technology, we have been able to utilize water-base drilling fluids without compromising the evaluation of the wells.”

**Homer Adams**
Director of Drilling, Engineering & Operations
Swift Energy
The dropoff tool is used to disconnect the wireline from the logging toolstring positioned on the hangoff sub and extending through the Portal bit. The wireline can then be retrieved before the hole is logged in memory mode while the drillpipe is tripped out.
Where gravitational descent of the Thrubit services toolstring on wireline is not possible in high-angle and horizontal wellbores, the rig’s mud pumps are used to pump the logging toolstring to the end of the drillstring. Especially in poor-quality or unstable boreholes, the smooth bore of the drillpipe ensures that the toolstring is easily deployed to the bit face. The pressured mud flow pushes the logging sensors out of the pipe, through the opening in the Portal bit. The top of the toolstring engages the no-go device in the hangoff sub to anchor it in place.

The functionality of the logging toolstring is checked and then the caliper is opened on the density tool. The three-axis accelerometer in the tool verifies that the density skid is oriented against the low side of the hole. With positioning and operability confirmed, the wireline and upper part of the dropoff and retrieval assembly are disconnected from the toolstring, returned to surface, and removed from the drillstring.

The exposed fishing neck at the top end of the logging toolstring makes it easy to retrieve the tools and any contained sources as necessary without having to trip pipe.

With the wireline removed, the ThruBit services logging tools operate in memory mode, logging the formations as they are conveyed on drillpipe tripping out of the hole. If only certain intervals need to be logged, a retrieval tool on wireline is used to return the toolstring to surface. This early retrieval saves time by enabling review of the memory data while drilling operations continue or the drillpipe is still being pulled out of the hole.

“The ThruBit quad-combo log data was an integral component in our process of making changes and optimizing our Eagle Ford wells. These logs gave us the data needed to make critical changes in our drilling and completion designs. The data we received was of the highest degree of quality and from an operations standpoint, your engineers, crews and equipment were some of the best I have had the opportunity to work with. ThruBit did a fantastic job. We will certainly consider them for any future work of this nature.”

Gary Simpson
Senior Petrophysical Advisor
Forest Oil Corporation
**ThruBit services logging sequence**

1. The Portal bit is used to ream to TD to prepare the borehole for logging.
2. The driller pulls the bit off bottom to provide room for the logging toolstring, which is pumped through the drillpipe.
3. The toolstring is pushed through the Portal bit opening into the open borehole, where functionality is verified, and then the wireline is disconnected and removed from the drillpipe.
4. Logging in memory mode occurs as the pipe is tripped out of the hole.
5. Once logging is complete, the Portal bit at the end of the drillpipe and toolstring are pulled up into the casing.
6. A retrieval tool is lowered on wireline to latch onto the toolstring and return it to surface.
7. With the logging toolstring recovered from the drillpipe, drilling or other operations can resume while the logging data is reviewed.
In a Eagle Ford horizontal well in South Texas, ThruBit logging services were deployed for memory logging via the pumpdown technique. The triple-combo data was used to produce a petrophysical analysis from which reservoir quality could be determined. Data from a nearby vertical well was combined with the sonic and density measurements from ThruBit logging services for an enhanced calculation of stress along the lateral.

This analysis was input to the stimulation design in which intervals of similar reservoir and completion quality were grouped by the completion advisor in the Mangrove* engineered stimulation design in the Petrel* platform to produce an engineered completion strategy. The well was then stimulated according to the resulting engineered completion strategy, flowed back for cleanup, and logged with the Flow Scanner* horizontal and deviated well production logging system conveyed on the MaxTRAC* downhole wireline tractor system.

Analysis of the Flow Scanner system’s production logging shows that 89% of the perforation clusters are producing oil, a significant improvement over the benchmark average for most geometrically spaced Eagle Ford completions. The well was producing in excess of 1,000 bbl/d of oil at the time of logging.

Accurate petrophysical analysis based on ThruBit services triple-combo data was critical input for the completion advisor design of an effective engineered completion.
Flow Scanner system’s production logging confirmed the effectiveness of the completion strategy, with 89% of the perforation clusters (shown in red in the Zones track) producing oil.
Forest Oil Company had drilled and completed several wells in the Eagle Ford play in South Texas. The locations were drilled using MWD gamma ray logging to guide geosteering, but additional logs were not obtained in the high-angle wells and lateral sections. Subsequent analysis found that although the wells were drilled and completed in a similar manner, production varied widely. Some wells were producing significant amounts of high-salinity water, which indicated that the hydraulic fractures had penetrated below the Eagle Ford to provide a water migration pathway. Additional logging data was needed to optimize the landing section and improve fracturing placement while reducing stimulation and completion costs. However, Forest Oil had concerns about slickline retrieval that would be required to use LWD in conjunction with MWD and the large rig-time demands for conventional pipe-conveyed logging.

ThruBit through-the-bit logging services were selected to obtain a suite of logs in the next horizontal well to be drilled. Once the hole had been conditioned, the directional BHA was tripped and the Portal bit and hangoff sub were run in to TD. The quad-combo logging suite on wireline was then pumped through the drillpipe to TD and out the Portal bit. The wireline was disconnected and retrieved, and formation data was recorded in memory mode as the drillpipe was tripped out of the hole. When the logging toolstring reached the casing shoe and was retrieved on wireline, the Portal bit was readily available downhole to make a conditioning trip indicated by review of the logging data. Combining the logging run with the conditioning trip saved Forest Oil more than 24 h of rig time in comparison with conventional pipe conveyance.

The sonic and density data were used by the Forest Oil petrophysicists to derive rock properties and better understand the natural fractures. With this information, Forest Oil was able to better map new exploration targets from 3D seismic data. The analysis also helped guide the grouping of hydraulic fracturing stages on the basis of mechanical properties to confine the fractures to the productive formation. Grouping the stages saved on stimulation costs by reducing the volume of sand pumped into each stage by one-third while doubling oil production in comparison with the earlier wells.
Eagle Ford formation evaluation combines data from ThruBit services logging with cuttings analysis and computed rock properties to determine the optimal placement of fracture stages in a South Texas well. Although green gas spikes are seen throughout this interval in Track 5, the sweet spot in the horizontal extends from about W,700 to Z,400 ft measured depth. Onsite geochemical analysis of wellbore cuttings shows a marked increase in total organic carbon (TOC) and hydrocarbons generated by kerogen thermal breakdown (S2) in Track 2, key indicators of source rock quality. The spread between the P- and S-waves in the sonic data in Track 6 indicates anisotropy, possibly attributed to fractures. In Track 6, tracer logs from after the stimulation treatment verify that the stimulation program designed using the logging data created more complex fractures at each stage to open more rock to production.
An operator moving from the exploration to appraisal stage of a horizontal drilling program in the Mississippian Lime play wanted to improve logging efficiency without compromising data acquisition. Logging the horizontal section using conventional drillpipe conveyance typically took more than 48 h of costly rig time to run quad-combo and imaging logs.

With low sensitivity to well conditions, the UltraTRAC all-terrain wireline tractor can convey toolstrings at up to 2,700 ft/h. The UltraTRAC tractor applies the highest output force available for reliable conveyance even in challenging wellbore conditions. Active traction control and reverse tractoring improve maneuverability and minimize slippage. Not only is data acquired faster but decision making is also more timely because the tractor-conveyed tools return real-time data in comparison with memory logging on drillpipe conveyance. The streamlined efficiency of UltraTRAC tractor operations also improves safety as rig time is significantly reduced.

A ThruBit services quad-combo was run first in the 3,500-ft lateral section of three wells to acquire density, neutron, resistivity, and sonic data. High-quality FMI* fullbore formation microimager logs were then acquired to complement the logs from ThruBit services for formation evaluation, lithology identification, and mechanical properties estimation. The FMI microimager was conveyed on the UltraTRAC tractor through 7-in casing and 8¾- and 6¼-in open hole. The logging runs of ThruBit services and UltraTRAC tractor conveyance totaled only 24 h, about half the time required for drillpipe conveyance, and saved the operator USD 40,000 in rig costs.

The microimaging log obtained with UltraTRAC tractor conveyance provides a high-quality image of the carbonate beds in the horizontal section.
An operator new to the unconventional Mississippian Lime play needed to log a well in Barber County, Kansas, to aid in optimizing perforation placement and the length of the fracture stages. The highly variable lithology of limestone, dolomite, and siliceous deposits could not be properly evaluated with just a conventional MWD gamma ray log.

A quad-combo toolstring was deployed using ThruBit logging services with 4-in drillpipe. The toolstring was pumped to logging position through the Portal bit opening, and the horizontal lateral was logged in memory mode as the drillpipe was tripped from the well. Once the logging tools reached the casing, they were retrieved to surface by wireline. The 6½-in Portal bit was still downhole and was used to ream back to TD for a final cleanup trip in preparation for casing the well.

The high-quality data from ThruBit services logging proved critical in completing the well. Significant changes in lithology were revealed along the length of the lateral. With the insight provided by formation evaluation using the logging data, the operator shifted the stimulation focus to the toe of the wellbore, which exhibited better reservoir conditions. A brittleness curve computed from the sonic data was used to divide the stimulation into intervals according to rock type, with optimized stage lengths, pad sizes, and perforation clusters. The sonic waveform data identified where natural fractures were, from which a hydraulic fracturing program was designed to minimize the risk of early screenout. An additional fracturing stage was added that treated the entire horizontal interval of the well. The result was outstanding, delivering one of the top-10 Mississippian wells in Kansas in 2011.

**Case Study**

ThruBit services quad-combo logging identifies a top-10 Mississippian producer

“Utilization of the ThruBit technology allows Osage to customize the stage design of our fracture stimulation by targeting specific reservoir fabrics to optimize production potential.”

Benjamin W. Crouch
EVP, Osage Resources, LLC

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The quad-combo revealed significant variation in formation properties, as exemplified by the porosity range from 4% to 16% in Track 3. The sonic log in Track 4 was key for identifying fractures to guide the completion design for the horizontal lateral in the Mississippian Lime.
Robust batteries power consecutive 37 h of ThruBit services logging operations in deviated well

A well in Plaquemines Parish, South Louisiana, posed numerous problems for logging. From 10,000 ft to total depth at 12,700 ft, the hole was deviated at 42° and had numerous problem areas that would require reaming. The logging operation would have to be repeatedly paused to allow several-hour periods of circulation to address sticking and the high influx of saltwater and gas into the well. Instead of attempting risky and expensive LWD in these conditions, the operator selected deploying a logging suite using ThruBit through-the-bit logging services.

A 9¾-in Portal bit was used to ream past the problem areas on a conditioning trip to total depth. The logging toolstring was then deployed on wireline through the drillpipe and positioned through the Portal bit into the open hole. Operability was confirmed and the wireline was detached and removed for conducting memory mode logging as the pipe was tripped out. Well control was maintained and sticking prevented by rotating and circulating as necessary.

The numerous interruptions for circulating stretched the time required for completion of the logging operation to 37 h, during which the robust batteries of the toolstring provided uninterrupted power. High-quality logging data was obtained that would not have been possible with conventional wireline logging and at less cost and risk than LWD.

The high-quality logs obtained with ThruBit through-the-bit logging services identified a thick, good-quality potential reservoir despite the challenging wellbore environment.
Oasis Petroleum, Inc., needed to log a Bakken Shale well drilled to 29,766 ft MD with a 10,000-ft lateral section. The well’s geometry posed deployment challenges for logging: 29.5°/100-ft radius of curvature and deviation up to 91° from the vertical.

ThruBit through-the-bit logging services with a Portal bit were used for a reaming run to prepare the borehole for logging before running the production liner. Circulation was used to maintain well control and prevent sticking as the logging suite was deployed through the curve and extended lateral. Once the logging tools reached total depth, they were positioned through the Portal bit into the open hole for logging in memory mode as the pipe was tripped out of the well. All it took was this single ThruBit services logging run for Oasis to obtain high-quality petrophysical data for evaluating the Bakken section.

The high curvature and extended lateral of the Bakken Shale well were easily logged by reaming the hole with the ThruBit services Portal bit on the down run and then deploying the logging string to log in memory mode while tripping pipe out of the hole.
The high-quality logging data provided by ThruBit through-the-bit logging in unconventional reservoirs is a critical component of using the Mangrove design in the Petrel platform to simulate the hydraulic fracturing design. Mangrove design’s engineered process is based on reservoir characterization to provide smarter completion designs and better production.
This reservoir-centric engineered design conducted in Denton, Texas, used through-the-bit logging data from ThruBit services.
“Without the ThruBit system, there is no way we would have been able to get a log for this well.”

Geologist, South Louisiana
### Specifications

#### Measurement

| Output | Telemetry, memory, and gamma ray tool: gamma ray, three-axis acceleration, borehole temperature  
Array induction tool: induction resistivity, mud resistivity, optional SP  
Neutron tool: thermal neutron porosity  
Density tool: bulk density, PEF, borehole caliper  
Sonic tool: delta-t (compressional and shear velocities in fast formations)  
Spectral gamma ray tool: gamma ray, corrected gamma ray for uranium; potassium, thorium, and uranium curves. |
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<td>Logging speed</td>
<td>Telemetry, memory, and gamma ray; neutron, density, induction and sonic tools: 1,800 ft/h</td>
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| Range of measurement | Gamma ray: 0 to 1,000 gAPI  
Resistivity: 0.1 to 2,000 ohm.m  
Neutron: 0 to 60 pu  
Bulk density: 1.04 to 3.3 g/cm³  
PEF: 0.9 to 10  
Caliper: 18 in  
Delta-t: 42 to 155 us/ft |
| Vertical resolution | Gamma ray: 12 to 24 in  
Resistivity: 1, 2, and 4 ft  
Neutron: 12 to 15 in  
Bulk density: 9 to 12 in  
Delta-t: 24 in |
| Accuracy | Gamma ray: ±5%  
Resistivity: ±1 ms/m or ±2%, whichever is greater for the 60-in measurement  
Neutron tool: ±0.5 pu  
Bulk density: ±0.01 g/cm³  
PEF: ±0.15  
Caliper: ±0.2 in  
Delta-t: ±2 us/ft  
Th: ±3.2 ppm or ±5% of reading  
U: ±1 ppm or ±5% of reading  
K: ±0.5% (weight) or ±10% of reading |
| Depth of investigation | Gamma ray: 12 in  
Resistivity: 10, 20, 30, 60, and 90 in  
Neutron: 10 in  
Bulk density: 2 in  
PEF: 2 in  
Delta-t: 3 in |
| Mud type or weight limitations | None |
| Combinability | All ThruBit tools |

#### Mechanical

| Temperature rating | Triple-combo: 350 degF; quad-combo: 302 degF |
| Pressure rating | 15,000 psi |
| Borehole size—min. | 4 in |
| Borehole size—max. | Telemetry, memory, and gamma ray; induction array, and sonic tools: 14 in  
Neutron and density tools: 18 in |
| Outside diameter | 2.125 in |
| Length | Telemetry, memory, and gamma ray: 73.6 in  
Array induction tool: 185 in  
Neutron: 74 in  
Density tool: 128 in  
Sonic tool: 144 in  
Spectral gamma ray tool: 70.125 in |
| Weight | Telemetry, memory, and gamma ray tool: 45 lbf  
Array induction tool: 94 lbf  
Neutron tool: 63 lbf  
Density tool: 94 lbf  
Sonic tool: 60 lbf  
Spectral gamma ray tool: 38 lbf |

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