DRILLING & COMPLETION TECH DIGEST

LWD system provides real-time, memory-recorded bulk density, density porosity, ultrasonic caliper measurements

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THE SLIM DENSITY Neutron Standoff Caliper (SDNSC) system from **PathFinder Energy Services** is a logging while drilling (LWD) system that provides real-time and memory-recorded bulk density, photoelectric index, neutron porosity, density porosity and ultrasonic caliper measurements.

With a nominal collar size of 4 ¾ in., the system can perform measurements in hole sizes from 5 in. to 7 ½ in. The tools density/neutron/caliper sensor packages are housed in a non-magnetic drill collar. A separate upper LWD battery collar provides power to this tool and puts the density and neutron measurements closer to the bit. This system acquires data, then communicates to a telemetry controller via an internal bus.

The acquired real-time data is sent to the surface via mud pulse telemetry. The system has a borehole logging capacity of more than 300 hours and can operate in flow rates up to 375 gallons/min (GPM). It is modular to allow for configuration anywhere in the LWD BHA and has a dogleg severity of 30°/100 ft while sliding, 15°/100 ft while rotating.

The porosity measurement systems rely on the interaction between installed radioactive sources and the rock formations, to calculate values for bulk density (RHOB), photoelectric index (PE), neutron porosity (NLIM, NSAN, NDOL), and density porosity (DPHI). In addition to the nuclear measurements, the system uses ultrasonic transducers to measure standoff and caliper (CALI) readings that provide information about the diameter and condition of the borehole.

This LWD formation evaluation tool is HPHT rated 25,000 psi, 350°F (175°C) and uses a Californium (Cf 252) source for neutron porosity measurements. The use of a Cf252 neutron source with reduced radioactivity and relatively short half-life is considered to be more environmentally friendly than a standard neutron Am241+Be source.

A PathFinder Energy Services engineer on the rig floor installs a Cs137 gamma ray source into the Slim Density Neutron Standoff Caliper mandrel.

DENSITY MEASUREMENT

The density system uses a Cesium (Cs137) gamma ray source. There are 2 sodium iodide/photomultiplier detector assemblies axially separated from the Cs137 source. These density detectors are encapsulated in a tungsten-shielded body with windows to allow gamma rays from the formations to come in contact with these detectors but shields gamma rays traveling directly from the source to the detectors.

The depth of investigation for the density measurement is about 8 in. The density system primarily measures the formation densities directly in front of the detector assemblies. The detector assembly closest to the source is the near detector, while the detector assembly farthest from the source is the far detector. When the density detectors are flush against the borehole (zero standoff), the densities measured using the near and far detectors separately are the same except for small differences from the borehole fluid.

When the detectors have a non-zero standoff, the 2 detectors measure different densities because different mud volumes measured between each detector and the borehole wall. Since in general, the mud density is lower than the formation density, the near detector will generally read lower than the far detector. The density measurement system uses the difference between the near and far detector responses in several gamma ray energy ranges per detector and its dynamic standoff based processing algorithms to correct for these borehole effects. These corrections produce an accurate compensated density measurement.

NEUTRON POROSITY MEASUREMENT

The neutron system uses a Cf 252 source. The average energy output from the Cf 252 source is less than a standard LWD neutron measurement Am241+Be source, making the lower energy Cf 252 neutrons more sensitive to hydrogen content and produces a larger dynamic range in porosity response. The neutron system consists of a high-strength steel alloy chassis with measurement electronics and 3 neutron detectors.

These detectors measure counts from the source and produce a ratio between the near/medium, near/far, and medium/far detectors to calculate the formation porosity. The neutron count rates at these neutron detectors depend on the matrix of the density of the formation. Since limestone, sandstone and dolomite have different matrix densities, the calculated neutron porosity depends on which of these matrices is assumed. Neutron porosity can be presented as limestone, sandstone or dolomite depending on the matrix.

The measurements taken are mainly influenced by the presence of hydrogen in the formation and borehole surrounding the detectors. The neutron system is calibrated with reservoir rocks of various porosities at zero standoff.

CASE STUDY

In the Gulf of Mexico, **Chevron** required a suite of formation evaluation LWD systems to acquire real-time and recorded data in a directionally drilled 7½-in borehole to a sandstone target. PathFinder provided 4¾-in nominal collar size directional, gamma ray, resistivity, density, neutron, caliper and annular pressure services in this well.

Accurate and reliable LWD wireline replacement services were accomplished by acquiring, processing and presenting high-resolution, real-time and recorded LWD formation evaluation data to define the lithology, mineralogy, formation fluid volume and types up to and including the target sandstone formation.

In the LWD formation evaluation log plot, the track 1 gamma response shows a change in formation from shale to sand at x248 ft. The resistivity measurements in track 3 display thin interbedded formations between x248 ft to x260 ft. A significant increase in resistivity from x248 ft to x278 ft is observed. A hydrocarbon gas cross-over response from the track 4 density and neutron measurements occurs also from x248 ft to x278 ft, with an estimated calculated porosity of more than 30%. Note that the neutron and density curve scales are based on a sandstone matrix.

The LWD formation evaluation results of this well were very favorable for Chevron. The environmentally corrected formation evaluation LWD services – including the density, and neutron systems – accurately defined the formations lithology, mineralogy, and fluid volume and type of the target sandstone formation. A hydrocarbon "pay zone" was discovered and characterized in a relatively clean sandstone formation. Chevron continues to use the same LWD services in boreholes of various sizes with similar results.

Weatherford installs world's 1st permanent in-well optical seismic system offshore

WEATHERFORD **International** has announced the world's first-ever successful offshore installation of a permanent in-well optical seismic system in **BP Norway**'s G-24 injector well in the Valhall Field.

The milestone is the result of a 2-year collaboration on advanced completion technology with BP Norway to design and manufacture a system suitable for deployment in an injection or production well. The equipment was installed in March 2006. It consists of five 3-component optical accelerometer stations and an optical pressure/temperature gauge deployed with the production tubing near the reservoir.

"Weatherford's Life of Well optical in-well system is providing both continuous seismic and pressure/temperature monitoring data and is also interfaced to the existing permanent ocean bottom cable system. This allows for the simultaneous collection of permanent seabed and downhole seismic data, representing a significant milestone for the industry," said **Tad Bostick**, vice president for Weatherford's optical sensing systems.

"The installation of the in-well seismic sensors represents an important extension of the existing permanent seismic monitoring system over the Valhall Field. The new sensors allow for new applications and represent a means for calibrating the remote observations of production effects to the observations made in the well. The primary objective is improved management of water injection and production," said **Olav Barkved**, lead geophysicist for the BP Norway Valhall Field.

Weatherford's Clarion optical seismic system features advanced optical multiplexing based on Bragg grating technology. The system uses sensitive, miniature optical multi-component accelerometers to continuously monitor active or passive seismic signals throughout the life of the well. Each tubing-conveyed seismic station uses a active clamping system that optically couples the 3-C sensor to the casing and substantially decouples it from the production tubing. A Weatherford optical pressure/temperature gauge is deployed along with the seismic sensors on a single fiber-optical cable.

New JIP targets expensive wellbore stability problems

A NEW JOINT industry project (JIP) on wellbore stability methodologies will be aimed at reducing expensive well construction problems such as wellbore collapse and lost circulation.

"Wellbore stability predictions are central to casing and fluid plans, trajectories and drilling practices," said **William Standifird**, senior vice president of operations for **Knowledge Systems**, which is conducting the JIP. "Despite this importance, there is no industry consensus on stability analysis methodologies."

The objective of the Practical Wellbore Stability Prediction JIP is to identify and develop best practices for practical wellbore stability analysis, as well as develop guidelines to assess the relative priority of data types and the minimum data needed for effective modeling.

The project plans to examine about 250 wellbores from 5 regions around the world. Studies are planned for:

- US Gulf of Mexico deep water;
- US Gulf of Mexico shelf;
- Western Canada;
- Australian northwest shelf;
- North Sea.

John Jones, senior staff drilling engineer at **Marathon Oil Company**, said he sees a continuing need to spread fundamental wellbore stability modeling capabilities among engineering groups.

Knowledge Systems is currently enrolling participants. The study is set to begin in early 2007 and take about 1 year to complete.