100% core recovery over 3 runs in horizontal well marks a first on Petrobras’ Bonitas field

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FOR THE OIL company, the two most important parameters in formation evaluation are the amount of hydrocarbon in place and the amount that’s economically recoverable. Coring provides the only means of access to the relevant parameters of porosity and permeability without requiring interpretation, as well logs would.

This means that core samples are one of the most valuable sources of data for the study of subsurface rocks and reservoirs, making coring a vitally important method of obtaining data for geologists, drilling engineers, petrophysicists and reservoir engineers.

Halliburton’s Security DBS drill bits recently cut and recovered three cores totaling 52 m from the 8 ½-in. horizontal hole of a Bonitas well for Petrobras, marking the first time that 100% core recovery was achieved in a horizontal well in Brazil.

The 52 m of core were cut and recovered from well 8-BO-24H-RJS over three runs at various measured depths. An 18-m core was taken at 3,317 m on the first run; a 16-m core was taken at 3,894 m on the second run; and an 18-m core was taken at 4,267 m on the third. In each run, coring occurred at a well inclination of at least 65°.

SYSTEM DESIGN

The Bonitas field formation is a medium-hard fractured sandstone with compressive strengths ranging from 15 kpsi to 20 kpsi, with calcareous cementation. Due to these harsh well conditions, mud losses had previously limited core recovery to just 29% of 18 m cut.

To withstand the difficult conditions of the field at high inclinations, Security DBS provided a conventional 8 ½-in. x 6 ¾-in. x 4-in. core barrel system with a double-shoulder thread that increases resistance to torque, bending and fatigue.

Criteria for selection of drilling fluid included the basic functions needed for drilling:

- Cool the cutting structure.
- Maximize ROP.
- Control formation pressures and hole stability.
- Clean the hole as formation is cut.

On top of that, the oil-based mud selected and used for all three runs on Bonitas was designed to satisfy these capabilities:

- Prevent alteration of rock and fluid properties.
- Hold mud weight within a window of 8.1/8.2 ppg.
- Regulate flow rate to protect the core.
- Achieve maximum core recovery.

The core barrel system also used fluted aluminum inner tubes, or seamless inner barrels that are internally fluted over the axial length. This allowed for further improvement in drilling fluid displacement by eliminating hydraulic resistance and hydraulic lock. In addition to reducing the core contact frictional area, the fluted design reduced the effective ID of the barrel for better core support, thus minimizing wedging and core jamming for better core recovery.

**CORE BIT DESIGN**

Because the primary objective of coring is to recover a formation sample suitable for testing, additional design factors were considered for the core bits on top of those used for drill bit selection.

<table>
<thead>
<tr>
<th>COREHEAD TYPE</th>
<th>SIZE</th>
<th>LENGTH (M)</th>
<th>DEPTH IN (M)</th>
<th>CUT LENGTH</th>
<th>REC. LENGTH</th>
<th>%</th>
<th>HOURS</th>
<th>ROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC3937</td>
<td>6-3/4-in. x 4-in.</td>
<td>18</td>
<td>3317</td>
<td>18</td>
<td>18</td>
<td>100</td>
<td>3.7</td>
<td>4.8</td>
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<tr>
<td>FC3937</td>
<td>6-3/4-in. x 4-in.</td>
<td>18</td>
<td>3894</td>
<td>16</td>
<td>16</td>
<td>100</td>
<td>2.9</td>
<td>5.5</td>
</tr>
<tr>
<td>FC3843</td>
<td>6-3/4-in. x 4-in.</td>
<td>18</td>
<td>4267</td>
<td>18</td>
<td>18</td>
<td>100</td>
<td>3.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Overall Performance</td>
<td>52</td>
<td>52</td>
<td>100</td>
<td>10.4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FC3000 core head technology from Security DBS was used to cut and recover 52 m of formation over three runs.
Three additional important objectives for Bonitas were identified as:

- Shaping the core correctly.
- Avoiding core jamming.
- Reducing fluid invasion of the core.

The coring system for Bonitas used 6 ¾-in. x 4 in. FC3000 core heads based on the proven bit design platform of the FM3000 Series. It uses a Transition Drilling Model to simulate drilling through a change in rock strength, such as from sandstone to shale. It also uses a new cutter/rock interaction model to calculate the amount of torque per revolution each cutter experiences through the transition layer. As a result, the design simulation models allow evaluation of how the cutting forces are affected when drilling transitions of hard or soft rock.

Trouble zones can be identified where impact damage could occur, then specific features such as profile shape, blade count, cutter back rake and impact arrestor location can be manipulated to improve performance.

Additionally, because FC3000 core heads are designed using global force balancing, lateral and axial vibration are reduced and ROP is maximized as energy balancing evenly distributes cutter forces, reducing impact damage and uneven wear.

The FC3000 design capabilities also include use of the latest PDC cutter technology. The FC3937 used for the first two coring runs incorporates highly abrasion-resistant Z3 cutters. They were developed after research identified Thermal Mechanical Integrity (TMI) as a third dimension of PDC cutter failure, in addition to impact and abrasion.

TMI failure is defined as loss of diamond that occurs due to a combination of thermal degradation and force and is a measure of cutter toughness as wear and thermal degradation occur. New testing capabilities enabled development of cutters with very high TMI.

Similarly, the FC3843 core head used on the third core run incorporates Elite Series Deep Ring Claw PDC cutters, which provide impact resistance and durability, as well as stability and bit life.

**OPERATIONS**

Using the FC3000 core head for the first two coring runs, the conventional coring system with fluted aluminum barrels cut the first 18-m core at 3,317 m depth. During this run in the Macae formation (Quissama), loss of mud at the end of the cut was observed. As a result, a core of 16 m was planned for the second run, which employed the same core head design to cut and recover the planned 16-m core from 3,894 m to 3,910 m. On the third run, still inside of the Macae formation, the FC3843 core head was used to cut and recover a full 18-m core from 4,267 m to 4,285 m and experienced no problems running in, coring or retrieving the core barrel.

Compared with the total of 5.22 m recovered previously in offset well EN-51HP using other coring systems, the conventional system with FC3000 core head technology from Security DBS recovered all 52 m of formation, becoming the first coring operation in Brazil to ever achieve 100% core recovery from a horizontal well. As a result, Petrobras obtained all required petrophysical, reservoir, drilling and geological data without the need to run SideWall Cores and Wireline logs.