Reducing risk to maximize drilling performance

To meet drilling challenges, such as hole sections with long steep inclinations and severe doglegs, the keystone of a new drilling campaign offshore Thailand includes use of rotary steerable systems instead of the downhole motors traditionally used there. Here, Schlumberger’s Ragan Crowell, M Sarfraz Balka and Hugh H Donald and Smith Bits’ Richard Hill discuss the design and technologies used to drill the successful first well in this campaign.

Up-and-coming Thailand-based independent E&P company Salamander Energy has established a solid production base in several key Southeast Asia locations, including the Bualuang field in the Gulf of Thailand. Now it plans to expand that footprint from anchor assets with material but relatively low risk, with step-out exploration, appraisal, and development opportunities. This approach means that wells drilled from existing platforms will have longer sections, with steep inclinations, and more severe doglegs to land in the shallow reservoirs. The well discussed here, BA-12H ST2, has a 1000m tangent section with an 80° inclination and average dogleg severity (DLS) of 4-5°/30m (Figure 1).

With a goal of growing production and increasing reserves, the drilling program also includes long horizontal sidetrack wells and horizontal sections placed very close (2m in some cases) to the roof of the reservoir, a strategy to help minimize water breakthrough (another drilling program goal) and that contributed significantly to increased oil production 2010/11.

The combination of increased well complexity, along with the shallow reservoirs and soft formations that characterize offshore Thailand, made the operator re-evaluate its drilling operations, which included a bottomhole assembly (BHA) design that used traditional downhole motors for steering.

![Figure 1: Profile and plan view of planned well path for BA-12H ST2.](image-url)
To reduce the risk of problems – such as stick-slip, vibration, and poor hole quality and wellbore geometries – the company wanted to use a highly engineered approach. For maximum operational productivity and efficiency, the goal is to drill these wells in just two runs: 1) surface to landing in the reservoir; and 2) horizontal section through the reservoir to total depth (TD).

Key drilling operation aspects to be addressed include optimum BHA design – including the right steering system and drill bit, logging-while-drilling (LWD) tool – and the right drilling fluids.

In 2010, the operator brought in Schlumberger as the drilling contractor, and together the team has completed two successful campaigns using downhole motors. With the increased challenges and raised performance bar of their third campaign together, the service company is providing a new set of technologies and services to help the operator meet its goals. This technology set, which features several technological and regional ‘firsts’, includes:

- BHA for 8.5in hole landing section (surface to landing) made up of: PowerDrive Archer high build rate rotary steerable system (RSS), EcoScope† multifunction LWD, and a Smith Bits 8.5in MDi519LBPX polycrystalline diamond compact (PDC) bit with 19mm PDC cutters, which was validated as suitable for use on the high build rate RSS using the Smith Bits IDEAS drillbit design platform.
- BHA for 6.125in horizontal hole section (to TD) made up of: PowerDrive X6 RSS and PeriScope bed boundary mapper for geosteering.

**Landing section**

**Rotary steerable system instead of motor.** With its shallow reservoirs and soft formations, drilling operations in the Gulf of Thailand have been dominated by traditional downhole steerable motors. These motors are able to meet the build rates and high dogleg requirements that are not easily met with some RSSs because of the soft formation. However, mud motors have lower rates of penetration (ROP) and result in coarser holes than RSSs, which can lead to problems later when running casing and downhole equipment such as sleeves. Additionally, torque and drag modeling for the current well showed that, after 2000mMD, no slackoff weight would be available to slide the motor to achieve the build rate required to hit the target. With the increased complexity of the required wellbore profiles, need for precise placement close to the reservoir roof, and the goal to complete this section in a single run, the operator wanted to achieve the best drilling performance and hole quality, so they decided to use an RSS. To achieve the ROP, required consistent build rate, DLS, and accurate wellbore placement, the team selected the high build rate RSS and the multifunction LWD tool for geosteering. This well was the first time this RSS and LWD tool had been used in Asia and only the second time worldwide that this RSS and LWD tool have been run together.

This RSS has been designed to deliver high build rates from any inclination and was used to improve steering in soft formations, where sediment washouts from mud flow can reduce BHA steering capabilities.

**Logging-while-drilling.** The multifunction LWD tool, with gamma ray, resistivity, density and neutron measurements co-located in one collar close to the bit, delivered the crucial geosteering data vital to landing the well in the correct location in the reservoir. With a well plan requiring the horizontal section of the well to run parallel to and just 2m total vertical depth (TDV) below the reservoir top, correct identification of this marker is critical, and fast, accurate decisions must be made to achieve an accurate and smooth landing and to avoid drilling a borehole shape (such as J-shaped) that could adversely affect production.

However, correlation for landing in the Bualuang field is difficult and marker locations are hard to predict. The only key markers seen consistently across the field are the shale two marker and T4.1 top reservoir. These markers, however, cannot be identified with gamma ray and resistivity alone; density and neutron values are required to confirm, so the multifunction tool was essential. The multiple co-located measurement capabilities close to the bit in this latest version of the LWD tool mean all measurements are made at the same time and depth, which allows markers to be identified as soon as they are encountered, without wasting any drilling interval, ultimately improving the probability of hitting the target with the appropriate deviation to optimize the reservoir section.

**Bit selection using IDEAS platform.** Offset runs, using data from the Smith Bits DRS drilling record system, combined with extensive local bit

† Japan Oil, Gas & Metals National Corporation (JOGMEC), formerly Japan National Oil Corporation (JNOC), and Schlumberger collaborated on a research project to develop LWD technology that reduces the need for traditional chemical sources. Designed around the pulsed neutron generator (PNG), the EcoScope service uses technology that resulted from this collaboration. The PNG and the comprehensive suite of measurements in a single collar are key components of the EcoScope service.

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Figure 2: Left images show axial (top), torsional (middle) and lateral (bottom) vibrations for a stable bit and right images show an unstable bit modeled under identical conditions. (Graphics not to scale)
experience, indicated that the geological formations to be drilled in this application were soft and that a 519-type (five blades with 19mm PDC cutters) PDC bit provided the best combination of ROP and durability.

The compatibility between PDC bit and PowerDrive Archer RSS is critical if maximum performance is to be achieved from this drilling system. While 519-type PDCs are commonly run in the Gulf of Thailand, a 519-type PDC bit had not been run anywhere globally on the high build rate RSS, which is typically run with six- to eight-bladed designs that use 13mm or 16mm PDC cutters. For experienced drilling personnel, the use of a five-bladed PDC bit with 19mm cutters with an RSS in a soft formation seems instinctively too aggressive and likely to prove difficult to steer and generate variable and erratic torque, or torsional vibration.

There was understandably some concern as to whether such a so-called ‘aggressive’ bit type would prove to be steerable while maintaining a high ROP. Using the IDEAS platform, a thorough, and engineered, analysis of the entire application (bit, BHA, drillstring, well profile, drilling parameters and geology) was undertaken to address the four KPIs of steerability, stability, ROP and durability.

Extensive analysis has shown that an unstable bit can reduce the DLS potential of PowerDrive Archer RSS by over 20% so the use of a stable bit design with the high build rate RSS is critical. The stability of a PDC bit on PowerDrive Archer can only be determined through the use of IDEAS modeling.

To select the optimum bit, the high build rate RSS approved PDC bit selection process was followed, which involves pre-drilling dynamic finite element analysis (FEA) modeling using the drillbit design platform. FEA is used to evaluate bit performance for the expected geological conditions and literally every component in the BHA and drillstring design, under typical drilling parameters in the planned well profile to meet the unique combination of these conditions for a specific run. The selection process, through a number of steps, gradually reduced the initial data set of multiple bit types (five- and six-bladed with 16mm and 19mm cutters) modeled down to the final MD519LBPX (519) PDC bit that was used to successfully drill the well.

Figure 2 shows output from an IDEAS simulation comparing bit vibrations for two different bits modeled under identical parameters. The graphs show that, for this particular application, there is a big difference in bit stability between the two different designs, even though they look very similar.
Results. With this drilling system design, the team achieved an average ROP of 56.8m/h – compared to the field average ROP with a positive displacement motor of 34.2m/h (Figure 3) – and landed the section as planned, in one run and without incident. This improved ROP was despite controlled drilling for sections of the run. Intervals of higher torsional vibration were observed, but were within the specifications of the PowerDrive Archer RSS and so did not negatively impact directional control. A smooth tangent section (DLS < 0.3°/30m) was achieved as was smooth running of 7in liner to TD (Figure 4).

With these excellent first-time-use results, the operator is planning to use this solution approach featuring RSS for future Bualuang wells with similar criteria.

Horizontal section
The final 6½/in horizontal section was drilled with the PowerDrive X6 RSS and the bed boundary mapper. With nine successful well placements in the previous campaigns, this LWD tool has reliably identified reservoir boundaries by detecting resistivity contrasts, and in some cases has also been able to delineate other geological features. Probable shale plugs were successfully interpreted from inversion of the LWD data, which improved geological understanding in the field, helping to maximize the production.

The LWD tool was used in this well to steer the well trajectory into the high-quality reservoir just 1.2m TVD from the roof of T4.1 reservoir, avoiding any conductive layer. Using the RSS ensured efficient but smooth steering with full rotation. The use of this RSS and LWD service together allows quick corrections to be made to maximize well length in the reservoir and hence production, while maintaining a smooth wellbore trajectory ensuring ease of running completions.

Conclusions
This case study highlights why it is important to continually examine problems and question conventional wisdom about both the domain challenges we encounter and the technologies we use to solve them.

Conventional wisdom said that mud motors were the best choice for soft formations and high DLS wells, and that a five-bladed bit with 19mm cutters was intuitively too aggressive for this drilling scenario. By using proven technologies, in new combinations – the high build rate RSS with the multifunction LWD tool and the right bit – the operator was able to meet these challenges and the improved drilling performance objectives. Advanced software technology, such as the drillbit design platform, makes it possible for teams to accurately analyze the many combinations of factors and data that experience alone cannot account for.

Ultimately, this case study showed how to reduce risks using proven technologies in new combinations to improve drilling performance.

This was demonstrated by increasing the ROP by 66% in the landing section and achieving all drilling objectives, which included delivering a very challenging directional profile in soft formations, a smooth 1000m tangent section, and a horizontal section placed just 2m from the reservoir roof.

This was done in just two planned runs, without incident. OE

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