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Large Hole RSS for Shallow Kickoff: Directional Control in Soft Sediment

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Abstract

This paper describes the successful planning and implementation of the world's first kickoff from vertical in a 26-in hole using a rotary steerable system (RSS). The RSS assembly was used to kickoff and build angle in soft Gulf of Mexico (GoM) surface sediment in the riserless section. Previous directional attempts in 26-in hole in this formation using conventional positive displacement motors presented several challenges. These challenges included reduced rate of penetration (ROP) during slide drilling and increased wellbore exposure to the non-inhibitive drilling fluid. These factors together contribute to a significantly over gauged hole in the shallow, unconsolidated sediments, which has been estimated in some cases to be as much as 34-in.

The impact of such large holes increases mud and cement costs and also greatly reduces the probability of a successful cement job. The risks for inadequate axial support, isolation of shallow hazards and wellhead subsidence increase almost exponentially with hole size.

Soft shallow sediments provided two major challenges for the 26-in rotary steerable system:

1. Sustain enough side force to deflect the bottom hole assembly (BHA) as required to kickoff the well and build to the desired angle.
2. Improve overall ROP, therefore: reducing the hole susceptibility to washout, reducing consumables cost and lowering the risk and implications of unsuccessful cement jobs.

The new RSS was tested on two 26-in sections, both of which required kickoffs at 300 ft below the mud line followed by a 1°/100 ft build rate to an angle of 25° for setting the 22-in casing shoe. In both cases the RSS was able to deliver the desired build rates as well as delivering an overall increased ROP that resulted in a reduction in hole washout.

The introduction of rotary steerable systems for 26-in hole sizes now provides operators with the ability to drill wells from top to bottom with these systems and, therefore, fully exploit the advantages of improved borehole quality, maximized drilling efficiency, and ultimately reduced drilling costs.

Introduction

Rotary steerable systems (RSS) have revolutionized the way oilfield operators drill wells. The advantages of drilling with this technology are documented and have been proven in a wide variety of drilling applications often allowing E & P companies to push the drilling envelope, by providing access to more complex plays, doing so efficiently and reliably, and contributing to an overall reduction in lifting costs[1]. Figure 1 highlights how the advantages of using RSS can result in lower field development costs[1].

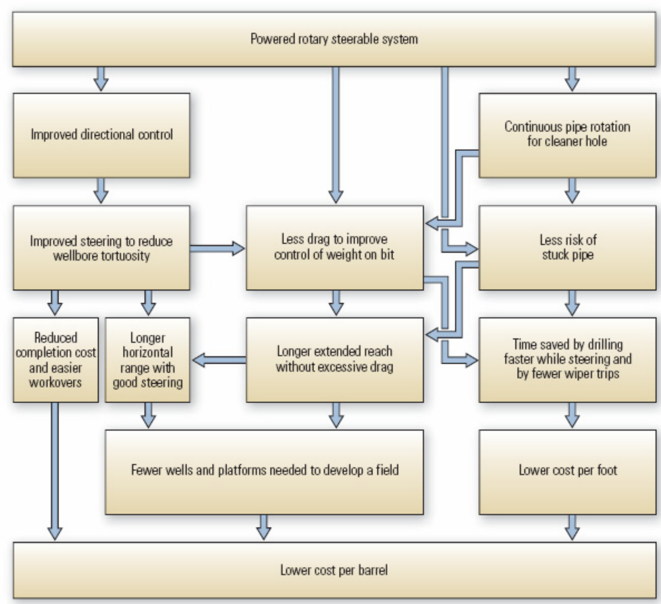

Figure 1: Advantages of rotary steerable systems

The need to access deeper reservoirs, high step-out targets and large-bore well construction requirements for HPHT (High Pressure High Temperature) and high production deepwater wells demanded that the advantages that rotary steerable technology brought to smaller hole sizes be delivered to large hole sizes.

This need drove the operator referred to in this paper to collaborate with the directional service provider to deploy their push to bit RSS in 26-in directional drilling application. The 26-in RSS system had previously been successfully used in vertical drilling applications. Previously the largest hole size that RSS had been used for directional drilling was 18¼-in.[2] Larger hole sizes have been drilled using the 18¼-in RSS with various hole-opening devices some distance behind the RSS tool. While this method does have its applications and operational efficiencies, it was not considered to be optimally suited to the application discussed here for the following reasons.

1. Too large an incremental hole size increase from pilot bit to reamed hole size (i.e. 18 ¼-in to 26-in).
2. RSS and hole opener at these hole sizes would impact the directional capability of the BHA.

The RSS system considered for this hole size had already been developed and commercialized by the directional service provider, although all previous application had been limited to vertical drilling applications[3].

Directional Challenges in Soft Sediments

Having realized the substantial benefit of rotary steerable drilling on many previous drilling campaigns, the operator was keen to deploy this technology in all hole sizes being drilled and thus extend the benefits from top to bottom of new wells being planned.

The system was to be put to test as part of a GoM field development set in almost 7,000 ft of water. The reservoir to be accessed stepped out 1.4 miles from the template at a depth of less than 9,000 ft below the mudline. This effectively translated into a displacement to True Vertical Depth (TVD) ratio of approximately 0.78, placing it within the industry-accepted envelope of extended reach drilling (ERD). To intercept this reservoir at an inclination that conformed to the drilling basis of design required deviation from vertical within 300 ft of the mudline, while well construction and delivery requirements called for 26-in hole at these depths. Figure 2 illustrates the typical trajectory for the wells discussed in this paper.

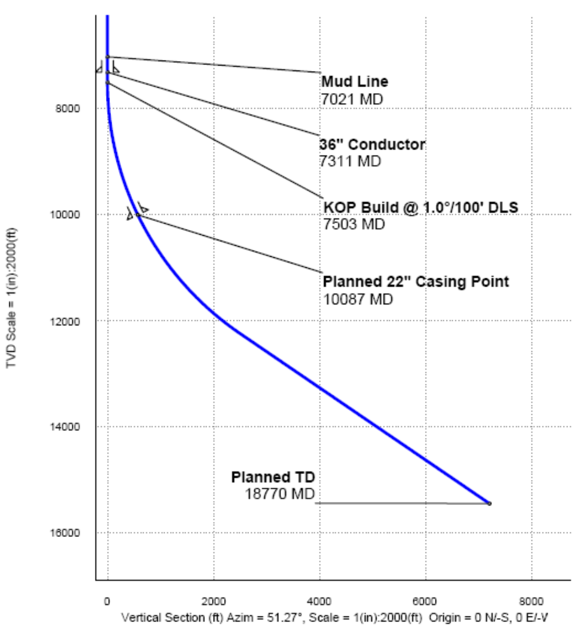

Figure 2: Typical well trajectory.

The operator's prior attempts at drilling large, shallow deviated wellbores in deepwater had proven highly challenging. Conventional mud motors were used and their limitations were evident. Performance summaries of these wells are discussed below.

Well AA-2: High levels of stick-slip were observed. The inability to mitigate this severe stick-slip along with insufficient revolutions per minute (RPM) to properly clean the hole resulted in the assembly twisting off, resulting in an expensive deepwater fishing job. The fishing job was unsuccessful and a 2-day sidetrack operation was required to recover the well. The ability to increase surface RPM is key to mitigating the stick-slip vibration mode. Drilling with positive displacement motor(PDM) limits the surface RPM between 40 to 60 RPM due to fatigue considerations resulting from the bend housing setting. This RPM restriction can also impact the hole cleaning while drilling. Surface RPM >80 rpm has been proven to be beneficial for effective hole cleaning. An example of the BHA used to drill these wells is presented in Figure 3.

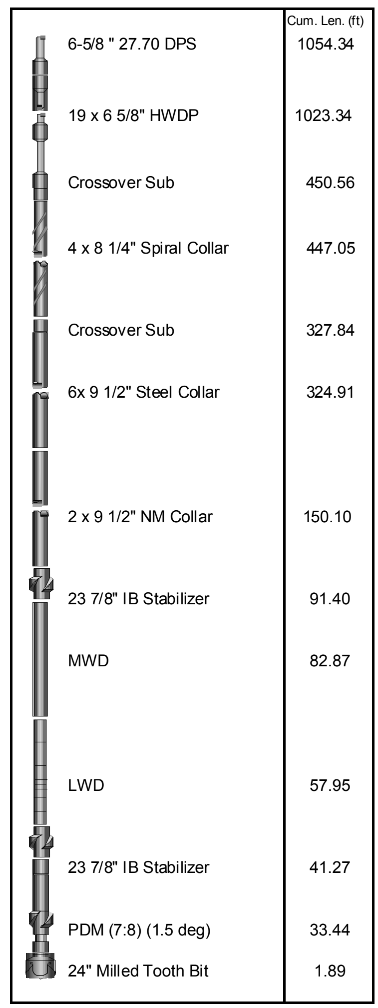

Figure 3: 24-in PDM BHA used for earlier directional wells.

Well AB-3: Drilled with a PDM suffered from lower than expected overall ROP, due to a significantly reduced ROP while slide drilling through a tough formation. The natural tendency of this formation pushed the assembly away from the intended direction and so a high percentage of time was spent slide drilling to ensure that the directional objectives were achieved. As with well AA-2, high levels of stick-slip were prevalent throughout the run, thus contributing to further reduction in ROP. Overall ROP for this section was 30% less than the average of other 24-in sections drilled in the field in 2006. Figure 4 compares the ROP of four wells drilled in this field in 2006 with identical PDMs. Note the overall reduction in ROP for the wells discussed, AA-2 and AB-3, both directional, when compared to the two remaining wells, both vertical. This reduction in ROP is attributable to both the reduced ROP while slide drilling as well as the less efficient use of the input drilling energy in the system, as more of this energy is dissipated through shock and vibration. The average length of these sections is 4,300 ft; the reduction in ROP is 30 ft/h. This represents almost two days of additional drilling time introduced when a PDM is used to drill a directional interval.

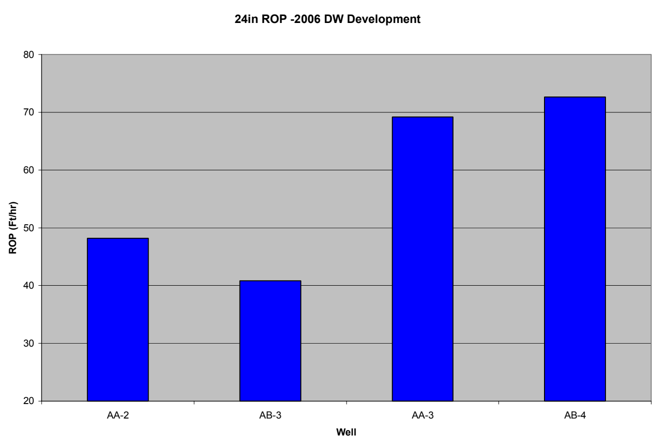

Figure 4: Field ROP comparison: vertical versus. directional wells.

The challenges of shallow directional work in deepwater do not end with drilling. Once the wellbore is drilled, high volume, high-risk cement jobs always follow. A good cement job is critical at this stage, since this string typically provides the axial support for the wellhead, blow–out preventers (BOPs) and ancillary subsurface components. A poor cement bond or channeling during or after the cement job may also result in insufficient isolation of shallow flow hazards, which have the potential to bring drilling to a premature end.

Drilling these shallow directional sections often results in an over-gauged hole, introduced via the interaction of the drilling fluid (typically gelled seawater in riserless applications) with the formation. The degree of washout is theorized to be directly related to the time to which the formation is exposed to seawater drilling fluid. Low ROP slide drilling, time spent orienting to slide, as well as non-optimized drilling impacting on ROP all effectively contribute to over gauged hole. Calipers obtained by measuring the circulating time of a marker fluid (often referred to as “fluid calipers”) on prior wells have indicated that these wellbore may “grow” from 24-in or 26-in drilled diameter to 34-in final diameter.

In directional hole, centralization of the casing is essential for a good cement job. Such large hole introduces major issues to proper centralization, since with inadequate centralization fluids will tend to have a higher annular flow rate on the wide side of the annulus, making fluid displacement (mud removal) difficult on the low side of the pipe. Additionally, the larger the hole size, for a given fluid pump rate, the lower the annular velocity of the fluids being pumped, again impeding mud removal and so impacting the quality of the cement job. Figures 5 and 6 below illustrate the impact of hole size on cement job quality for the wells described in this paper. A 28-in hole (2-in over-gauge) is compared with 34-in (8-in over gauge hole). Note the reduced cement coverage in the 34-in hole.

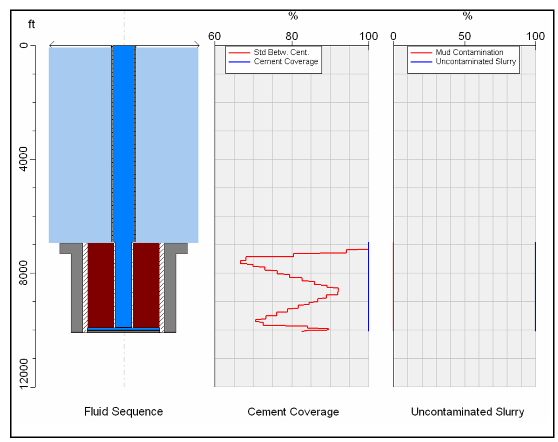

Figure 5: Cement coverage simulation for 28-in, 25° inclination wellbore.

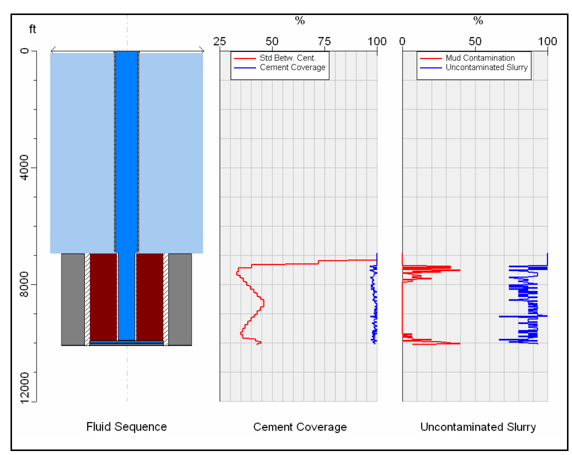

Figure 6: Cement coverage simulation for 34-in, 25° inclination wellbore.

The Way Forward

Having developed a thorough understanding of the challenges of shallow directional drilling in deepwater and given the requirements for the wells discussed in this paper, it became critical to the operator to improve on the performance of similar past wells. Rotary steerable systems were seen as the most appropriate solution. The benefits of 100% rotation while drilling, at high RPM had been demonstrated on countless wells to improve ROP and aid in drilling optimization. By introducing this technology to these wells, it was thought that overall drilling efficiency would be improved by faster drilling with less borehole washout and with better control of downhole drilling shocks and vibrations. This in turn would lay the foundation for a better cement job and impact positively the overall success of the well.

While the potential benefits that RSS could bring to this project were clear, there was some uncertainty surrounding the ability of the existing 26-in tool to effectively steer and maintain control in soft sediments. The operator and service provider then entered into a massive technical and logistical planning effort to ensure the success of what would prove to be the world's first use of a RSS in 26-in directional drilling application.

Planning for Success

A prejob analysis was conducted to determine the compressive strengths of the shallow sediments. A Mechanical Earth Model or MEM, (a mathematical representation of the in-situ stresses, rock properties and pore pressure as a function of depth for a particular stratigraphic area), was developed for a typical well in this location. The model was populated with rock physical attributes, such as compressional and shear velocity, density, effective and total porosity, and volume of clay acquired through logging-while-drilling and wireline formation evaluation measurements, to determine the Unconfined Compressive Strength (UCS) for the formations to be encountered to 2,400 feet below the mud line. The UCS was then compared against the actual force with which the RSS pads would exert on the formation over the full range of expected flow rates. A proprietary, experimental correlation used to relate formation strength and pad force to build rate potential was established by the service company and used to estimate what range of build rate could reasonably be expected under the existing conditions.

The results from the MEM and subsequent analysis demonstrated that the 26-in push-the-bit rotary steerable tool would be able to build at least 1°/100 ft across this interval.

The performance of the RSS in a 26-in borehole was to be evaluated over a 2 well program. The well trajectories were planned to kick within 100 ft below the mudline and designed with the recommended build rate of 1.0°/100ft. The BHA design incorporated a flex joint to improve dogleg capability. Figure 7 illustrates the planned 26-in RSS BHA.

The measurements while drilling (MWD) tool was run below the logging while drilling (LWD) to provide real-time (RT) continuous directional and inclination measurements closer to the bit. These measurements would be transmitted to the surface at 6-in intervals; therefore, allowing the directional team earlier evaluation of the BHA tendency and the opportunity to respond earlier to undesired directional tendencies. A milled tooth bit (IADC code 115) was selected due to the formation expected to be encountered. Seawater was used as the drilling fluid.

The objectives of the runs were clearly defined:

1. Kickoff and drill a riserless, 26-in directional hole according to the required trajectory.
2. Minimize borehole washout for a successful 22-in casing run and subsequent cement job.

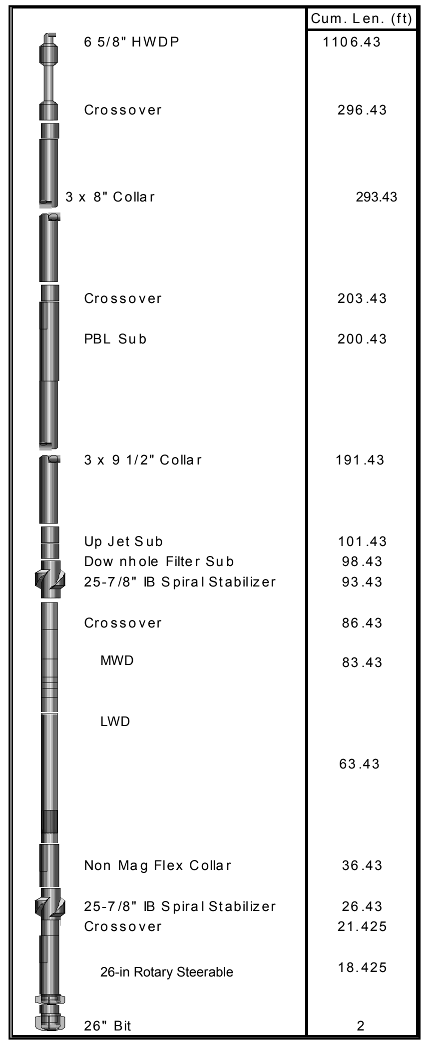

Figure 7: Rotary steerable BHA for drilling 26-in section.

Meeting the Challenge

Well #1: The trajectory called for kicking off 50 ft below the 36-in conductor and building at 1.0°/100ft to an inclination of 25.8° at section total depth (TD). The ROP for the first few stands drilled ranged from 360 to 540 ft/h. The early surveys showed the RSS tool to be building angle at 0.3° to 0.6° on each survey with a total dogleg output of 0.4° to 0.7°/100 ft.

With approximately 3° of inclination in the hole, a switch to a gravity toolface was made and the well lined up the desired azimuth. Multiple settings were then used to keep the well on the desired trajectory on the way to the planned casing point. Figure 8 present plot of continuous inclination versus depth. The final survey showed 22.5° inclination. Shock and vibration issues were nonexistent. The well was successfully cased and cemented.

Well #2: The trajectory called for kicking off 100 ft below the 36-in conductor and building at 1.0°/100ft to an inclination of 25.8°at section TD. The lessons learned from the previous run were incorporated into this run, with BHA design and kickoff procedures adjusted slightly. As seen in the first run, the ROP slowed after the first few stands as more competent formation was encountered. Overall ROP on this section was ~ 170 ft/h compared to 115 ft/h on the previous run attributed to the improved practices implemented. The final survey showed 24.5°inclination. As on the first well, shocks and vibrations were non-issues while drilling. The well was successfully cased and cemented.

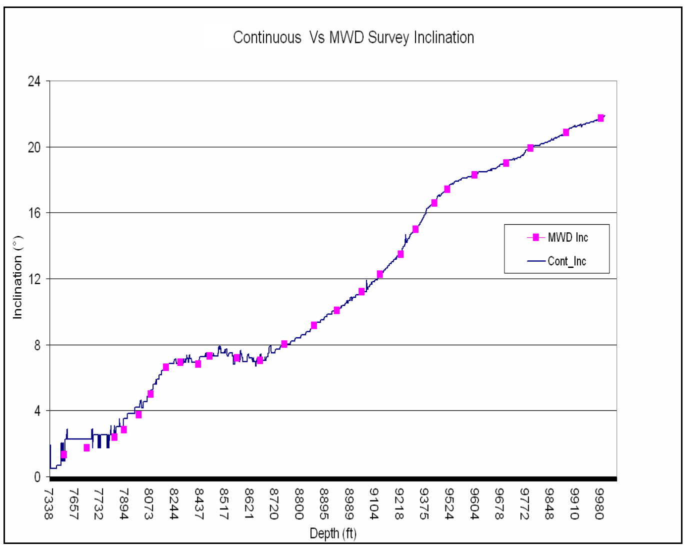

Figure 8: Continuous Inclination measurement from during first 26-in RSS directional run.

Conclusions

On the previous shallow directional wells drilled by the operator in the area, typical ROP averaged 50 ft/h, with vertical wells ROP averaging 70 ft/h. On bottom drilling time for the two 26-in sections done with the RSS proved to be 23.4 hrs for a 2706 ft interval on Well#1 and 15.9 hrs for a 2,696 ft interval on Well #2. This gives an average ROP for the wells drilled with the 26-in RSS of 137 ft/h. A 2,700 ft directional section drilled at the PDM ROP would require 54 hours. The 26-in RSS has been able to deliver an average time savings of 34 hours, representing a 63% reduction in drilling time. Figure 9 illustrates the comparison between PDM and RSS for large hole, shallow directional work in deepwater.

Average hole diameter (as determined by fluid caliper) for these two sections was 31-in, a 10% reduction in hole washout. The reduced washout is attributable to the reduced time that the wellbore is exposed to the seawater before cementing.

Based on the pre-drill objectives for the run, the 26-in RSS has delivered measurable evidence that meet these objectives. The evidence of these runs clearly demonstrates that the benefits of RSS can be translated to large hole sizes drilled directionally in deepwater environments. Introduction of this technology has been able to reduce the overall time spent drilling these directional sections by increasing the ROP, eliminating the need for slide drilling, and generally optimizing the drilling process by reducing unwanted downhole shocks and vibrations. The benefits of 100% of rotation while drilling lead to improved hole condition, which when combined with reduced time of exposure of the open wellbore to the seawater drilling fluid, reduces the potential for excessive washout and improves the chances of a successful cement job.

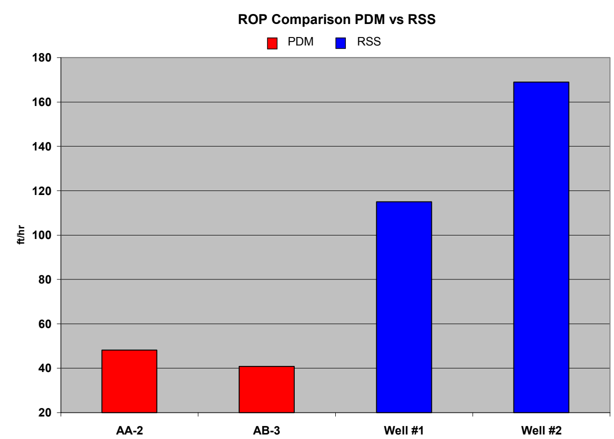

Figure 9: ROP Comparison in Large Directional Hole PDM versus RSS.

The applications for a 26-in RSS for shallow directional work in deepwater are not limited to those discussed in this paper. Already, deepwater operators and service providers are identifying opportunities for improving drilling performance using these tools in the following areas:

1. Directional work in shallow salt bodies.
2. Near-bit inclination measurements for anti-collision mitigation when exiting multiple well templates
3. Pushing bigger hole deeper, as required in many HPHT well construction designs

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