Case History

# North Sea – Three Wells Analysis

This case history showcases neotork utilization in a well (N05-01x) that was side-tracked from an existing well (N05-01) following a discovery, to better ascertain the size of the geological structure. After about 1,000 meters (m) drilled, N05-01x had to be abandoned because of a pressure incident forcing the operator to cement the whole BHA downhole. A third well was then drilled (N05-01xx), this time without neotork. Those three very similar wells, one drilled using neotork and the two others without, allow a clear comparison of the impact of neotork on drilling performance.

## Application Description

N05-01 was targeting a specific geologic structure in the Top Findorf sand. The well was drilled using a RSS powered by a PDM and the bit was a TK66 from NOV (IADC M222). At a depth of 2744m the 8 ½ section was completed and the well extended by a 6" drain. That drain hit a hydrocarbon bearing zone and tests identified good potential. To better define the size of the pay, a side-track well, kicking off from N05-01 9" 5/8 casing was decided.

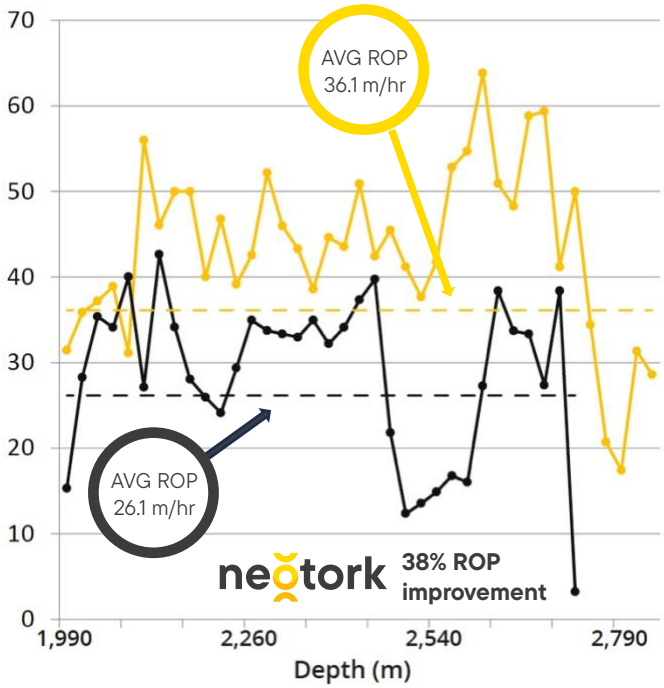
N05-01x was drilled using a RSS system. neotork was located at approximately 40m from the bit which was a PDC type TD506X from Baker Hughes (IADC M223). After 962m drilled and at the depth of 2832m, an inflow was observed. While trying to control the well, a crack occurred in the upper formation and the well started to lose mud from that level, while still producing water from the bottom. After a few attempts to solve this issue, it was decided to cement the whole BHA downhole and abandon that well for a second side-track.

N05-01xx was side-tracked from 1860m depth. The side-track assembly drilled down to 2150m where a new RSS assembly, powering a PDC bit TD506X from Baker Hughes (IADC M223), was run. This new assembly completed the 8 ½ section.

The lithology drilled on those three wells was identical however N05-01x was not vertical but had a small deviation, from 6° to 18° with a total TVD difference of 19m. N05-01xx had a hole angle ranging from 5° to 10°. The drilled rocks consisted mostly of salt, clay and at the bottom of the section a hard level of anhydrite and carbonate, which will be one focus of this case study. All three wells were drilled consecutively using the same contractors, and both N05-01x and N05-01xx used the same drill bit.

## ROP Difference N05-01 vs. N05-01x

N05-01 was targeting a specific geologic structure in the Top Findorf sand. The well was drilled using a RSS powered by a PDM and the bit was a TK66 from NOV (IADC M222). At a depth of 2744m the 8 ½ section was completed and the well extended by a 6" drain. That drain hit a hydrocarbon bearing zone and tests identified good potential. To better define the size of the pay, a side-track well, kicking off from N05-01 9" 5/8 casing was decided.



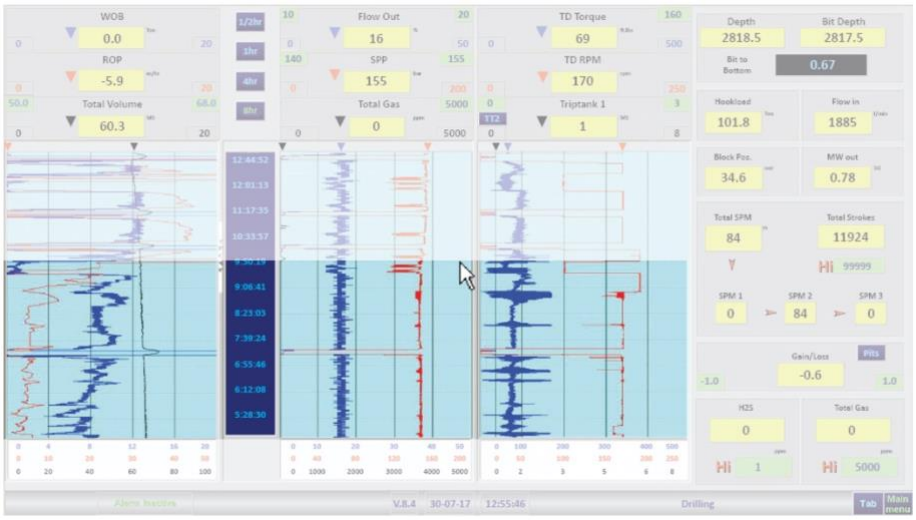
# Comparative Analysis N05-01x and N05-01xx

## Bit Wear

After the side-track was completed, the third well - N05-01xx - was drilled with an identical BHA and drill bit than N05-01x. A run of 543m was completed in 37.72 hrs (average ROP 14.4 m/hr). However, NO5-01x did not benefit as much from the easier salt and clay drilling conditions at the top of the section. In order to present the most unbiased comparison, this case study will focus on the bottom part of both runs where they crossed the Zechstein Group/Z2, predominantly composed of anhydrites and carbonates that are a notorious cause of lower ROP (as they tend to increase downhole vibrations and stick-slip).

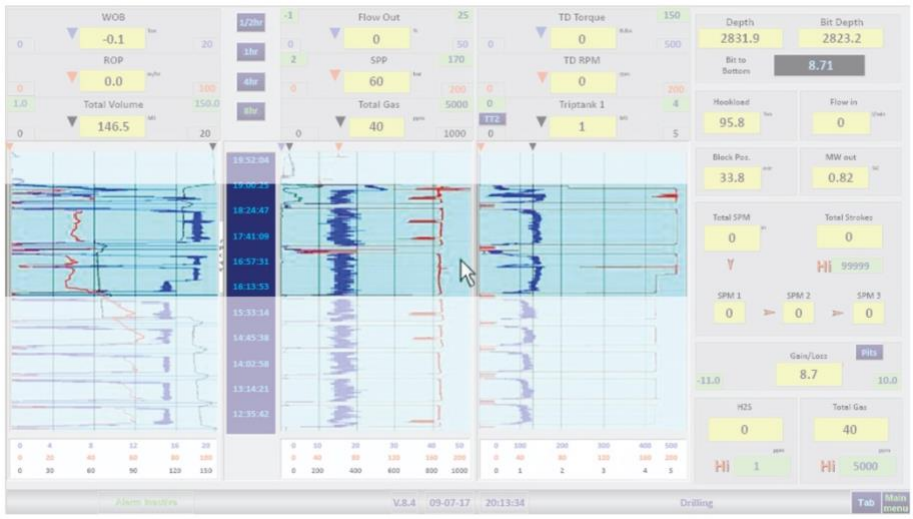
**N05-01xx**

The chart on the right is a screenshot of the driller monitoring panel whilst crossing that interval on N05-01xx. A WOB of 10 tons and RPM of 170 delivered a 5 to 7m/hr ROP but with highly erratic surface torque. Both the erratic torque, but also the need to control parameters to reduce stick-slip, are mentioned throughout the drilling report related to this interval.




**N05-01x**

The chart on the right represents the same interval when drilled using neotork on N05-01x. Due to the steadiness in the surface and downhole sensors, parameters could be optimised and WOB was pushed to 18 tons while RPM were increased to 200. As a result this section was drilled with an average ROP of 28 to 36m/hr; a fivefold improvement on what was achieved when drilling the same interval using same bit / assembly on N05-01xx.



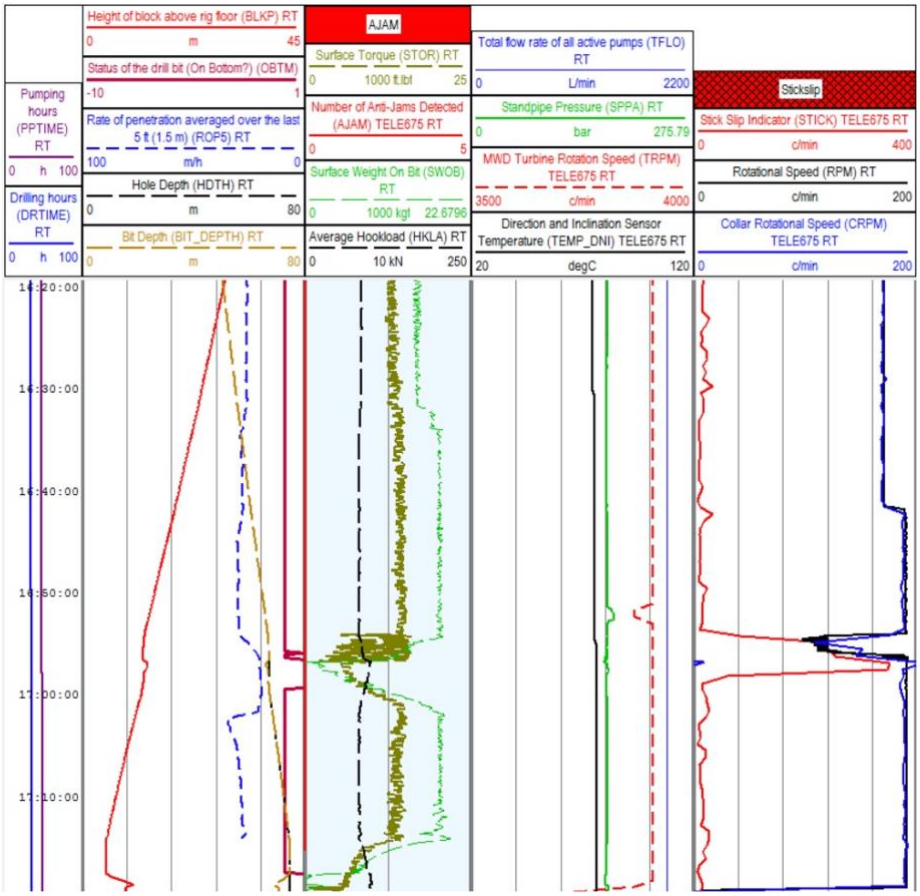
# Comparative Analysis N05-01x and N05-01xx

## ROP

Below are the results of drill-off tests done whilst drilling N05-01x upper anhydrite layer. These illustrate further neotork's ability to work at higher parameters.

| Depth Interval | WOB (T) | RPM | Torque (kFt.Lbs) | ROP (m/hr) | Slip & Stick | Shocks Level |
|---|---|---|---|---|---|---|
| 2767m – 2776m | 15 | 170 | 11 -12 | 26 | 3-10% ratio | 0 |
| 2776m – 2780m | 18 | 170 | 12 -13 | 29 | 3-10% ratio | 0 |
| 2780m – 2785m | 18 | 190 | 12 -13 | 31 | 3-10% ratio | 0 |
| 2785m – 2785.5m | 18 | 120 | 8 -15 | 20 | 3-10% ratio | 1 |
| 2785.5m – 2795m | 18 | 190 | 8 -15 | 29 | 3-10% ratio | 0 |

The tests show that neotork proved highly efficient under enhanced drilling parameters: stick-slip remained almost negligible and vibrations were at level 0 (see chart below). It is worth noting that a drastic drop in RPM had an immediate detrimental effect on stick-slip, as would be expected. Both RPM and WOB need to be balanced to secure smooth drilling conditions.



# Summary and Conclusion

While this analysis is incomplete, as for obvious reasons bit wear could not be compared, it can be seen that the performance delivered by the neotork BHA on the N05-01x well was a marked improvement on the results achieved with similar or equal bits/BHA on the two reference wells.

As all other conditions were equal, this improvement in performance can be entirely attributed to neotork and its ability to allow optimised drilling parameters. This was particularly evident when drilling tougher formations (anhydrite) where an 80% increase in WOB and 20% on RPM resulted in ROP multiplying up to fivefold through the same interval.

Statistics aside, the strongest argument for utilizing a new technology remains the positive feedback from third party users. Below, is an extract from the directional drilling contractor's report, highlighting the obvious benefits of using neotork.

Schlumberger

**BHA PERFORMANCE REPORT - DIRECTIONAL DRILLING** — BHA # 4

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| COMPANY | | RIG | | BHA Type: | Rotary Steerable(RSS) | | | |
| WELL | | FIELD | | | Date | Depth | Inc. | Azi. | TVD |
| Client Rep. | | Location | | In | | 1870 m | 2.7° | 312.0° | 1865 m |
| Directional Driller: | M. Boonen/J.Noordhoek | Job # | | Out | | 2832 m | 18.0° | 232.0° | 2813 m |

| BHA Objective: | Reason for POOH: | Drilling Problems | Low = x | High = xxx |
|---|---|---|---|---|
| Kick of from a whipstock in a direction of 232.deg and building from vertical to 10deg inclination. Hold inclination and azimuth untill a depth of 2752m and continue building from there to 27.9 deg inclination in the same direction. At 27.9deg hold inclination and azimuth and drill tangent to section TD of approx.4188m | Unable to get the well under controll by increasing the MW to the max. Well was still flowing w/o circulation. Decision was made in town to cement in the BHA, cut and POOH DP | Well Control | | xxxxx |

| Run Details | | | Bit Details | | PowerDrive Details | | BHA Component | Length | Size (OD) | Bit to |
|---|---|---|---|---|---|---|---|---|---|---|
| BHA Number | # 4 | | Bit Number | # 2 | Run Number | # 1 | 8 1/2" PDC Bit TD506X | 0.27 | 8 1/2" | 0 |
| DepthIn | 1,870 | | Size | 8 1/2" | Size | 6 3/4" | PD 675 w/ 8-3/8" Stab | 4.09 | 8 3/8" | 3.47 |
| Depth Out | 2,832 | | Type | PDC, TD506X | Type | PD X6 | PD SRX Slick | 1.70 | | |
| Total Ftg. made | 962 | | Manufacturer | Baker Huges | Control Stab | 8 3/8" | TeleScope 675 NF | 8.38 | | |
| Drilling m. (Rotary | 962 | 100% | Serial Number | 6013880 | Flex Collar s/n | n/a | 6.75" X-Over Sub | 0.72 | | |
| Drilling m. (Orient) | | 0% | Gauge Length | 4" | Control Unit s/n | 4011 | 8-3/8" NM Stabilizer | 2.07 | 8 3/8" | 16.02 |
| Total Drlg. Hrs | 27.85 | | Jets/TFA in2 | 6x12 / 0.663 | Bais Unit s/n | 52923 | 2 x 6-3/4" NMDC | 18.33 | | |
| Rotary Drlg. Hrs | 27.85 | | ROP (R) m/hr | 34.54 | | | GunDRILL Reamer | 1.94 | 8 3/8" | 36.42 |
| Orient Drlg. Hrs | 0.00 | | ROP (O)m/hr | #DIV/0! | Drilling Hrs | 27.58 | NeoTork | 5.45 | | |
| Reaming Hrs | 61.68 | | ROP (Avg.) m/hr | 34.54 | Operating Hrs | 96.28 | 10 x 6.75" Spiral Collar | 92.93 | | |
| Drilling Cmt. Hrs | 0.00 | | Bit Grading | | Rerun Hrs | 0.00 | 2 x Tri-Spiral HWDP | 18.72 | | |
| Circulate Hrs | 96.28 | | n/a n/a n/a n/a | | Cum. Hrs | 96.28 | 6 1/2" Jar | 9.87 | | |
| Total Circ/Op. Hrs | 96.28 | | n/a n/a n/a n/a | | | | 5 x Tri-Spiral HWDP | 46.80 | | |
| Mud Details | | | Drilling Parameters (Range over the run) | | | | 6 1/2" Accelerator | 10.01 | | |
| Type | Glydril | | | (Rotary) | (Orient) | String Wt | 3 x Tri-Spiral HWDP | 28.08 | | |
| Wt. (sg-lbs/gal) | | | WOB | 8-18 | n/a | mT | 5" DPS for OH | 2115.96 | | |
| Vis | 56 | | RPM | 60-190 | n/a | Up Wt. 103 t | X-over | 1.12 | | |
| | | | | | n/a | Down Wt. 93 t | 5-1/2" DPS (26.44 ppf) | | | |
| YP | 52 | | Pressure Bar | 141-169 | Press Δ: 30 | Rot Wt. 98 t | | | | |
| | | | | | Reactive: n/a | | | | | |
| Solids % | 34 % | | Calculated BHA Weights | | | Inc. @ 0.0° | | | | |
| | | | | | In Mud | Wt (Inc & Mud) | | | | |
| | | | | | 28 T | 28 T | | | | |
| | | | | | 21 T | 21 T | | | | |
| | | | | | 8 T | 8 T | Total Length | 2366.44 | | |

Before this run a whipstock was set at 232 azimuth at a depth of 1867.5m. The window was milled successfully and a second window elongation run been done. The bottom of the window was at 1865m and the rathole was drilled to 1870m with the second milling run.

The BHA was picked up as listed above. The MWD & PowerDrive were tested on surface and the PowerDrive was set into GTF mode 100% steering ratio 0 deg TF. To make sure the tool started straight away in the correct setting. The pipe got filled every 300m and circulated for 6 minutes with 1950lpm to prevent the crystalized salt and metal filings from the milling to plug the tools.

Went through the shoe with 400lpm and w/o rotation. Brought the flow up to drilling flow rate of 1950 lpm when through the window. Initiated drilling the kick off with 1950lpm, 141bar, 80 rpm, 8-12 Knm TQ and 5T WOB. Brought the rpm down when stabilizers and reamers went through the window. The parameters were gently increased in order to optimize the ROP. At a depth of 1890m was the kickoff confirmed and the steering ratio reduced to minimize DLS.

At the tangent angle of 10 deg at 1964m the PowerDrive was set into inclination hold mode. The ROP significantly increased in the Zechstein salt to 50-60 m/hr. The well was circulated clean at a depth of 2395m and pulled back to the shoe in order to pick up the remaining 5in DP. Ran in hole again and continued drilling the tangent.

The client and drilling engineer agreed the DD's proposal to optimize the trajectory by start building earlier and therefore reducing DLS in the trajectory. Went successfully through the first drillers target. During the whole section so far seen no stick slip and Torque been a flat line the run been a test for Neotorq tool that seemed to help smoothing out torque fluctuations and therefore helping to optimize ROP. The formation behavior changed at a depth of 2805m and the PowerDrive started dropping even though steering up. A little deeper at a depth of 2832m a sudden pressure increase of 60 bar, increase of WOB and increase in active mud volume was observed. The well was shut in immediately. Circulated out the influx using drillers method. Influx confirmed as Brine. Tried to kill the well with 1.84sg mud unsuccessful shut in pressure 14 bars due to logistics tried dynamic kill that succeeded. The day after a boat with new mud and chemicals arrived and started to increase the mud weight to 1.91 sg. The shut in pressure was 6 bar and the well was flowing without circulation. The decision in town was made to cement in the BHA and use wireline to cut of the 5in DP. Plug back with cement to 2100m.

***Conclusions and Recommendations:***

The kick off from the whipstock was performed with the PowerDrive in GTF mode, 0 deg TF 100 steering ratio. The whipstock it self gave enough inclination for the PowerDrive in order to see his reference piont, highside and kicked off succesfully. The BHA behaviour was really good, there were no left or right tendencies seen and PowerDrive was steering as required.

The NeoTorq tool that was used as field test run did a very good job, reducing the stick slip. In this scenario the tool started working optimum from a WOB of 12 ton.