

“On this demanding well, the IFE program enabled the operator to not only drill without a single well-control problem, but also save \$169,000 in related well costs. A unique waste management/disposal system, and VIRTUAL HYDRAULICS* software combined to establish new economic benchmarks for the drilling of HTHP wells.”*

Nick Hilbig, IFE Regional Coordinator

Well Information

Location Central Graben, Norwegian North Sea
Spud February/May 1999
Total footage drilled 16,300 ft (4968 m)
Temperature/Pressure 350°F/13,000 psi
Mud weight Up to 18 lb/gal (2.16 SG)

The Situation

An operator working in the Central Graben area of the Norwegian North Sea planned to drill an exploration well under HTHP conditions. This area is known for its difficult drilling conditions. Numerous well-control problems below the 9½-in. casing had impeded previous wells drilled in the area. In those intervals, the differential between pore pressure and fracture gradient can be as narrow as 0.2 lb/gal (0.025 SG).

For this well, the downhole temperature was expected to reach 350°F (177°C), with a pressure of 13,000 psi (896 bar). Previous wells in the Central Graben were drilled with water-base fluids to the 13½-in. casing shoe, followed by synthetic-base fluids to Total Depth (TD). Although the synthetic – base systems performed adequately in earlier wells, the water-base muds had difficulty coping with the highly reactive clays in the upper sections. Subsequent gumbo-related problems, including balling and stuck pipe, dramatically decreased drilling efficiency and overall economics.

For this Central Graben well, the operator was looking for an alternative to the previous systems used. The objective was to drill this and subsequent wells safely at cost-effective drilling rates, while still meeting stringent Norwegian environmental regulations.

The Solution

M-I SWACO recommended that the operator employ the INTEGRATED FLUIDS ENGINEERING* (IFE) service to plan both the drilling of the well and the subsequent management and disposal of generated wastes. After discussions with the operator, the M-I SWACO IFE team suggested that using an oil-base mud system from below surface to TD offered the best solution for safely and economically drilling the well. However, Norwegian environmental regulations strictly prohibit the use of oil-base mud in the upper intervals unless the generated cuttings can be reinjected.

For this wildcat, the nearest injection well was an hour away, and the expected high quantity of cuttings was beyond the capacity of conventional waste-collection and disposal systems. The challenge for the IFE team was to engineer an innovative waste management method that would facilitate inter-field cuttings transfer. An additional, critical goal was to ensure that the well was drilled safely, particularly when encountering the HTHP sections.



The IFE engineering team used an innovative approach to run oil-base mud and satisfy the Norwegian sector's strict regulations. The solution called for a unique waste-management process that included a modified, vacuum-driven cuttings-handling system, the construction of newly engineered DuoVac containers capable of securely containing the large quantity of waste and a continuous offloading/disposal system.

To minimize well-control problems and prevent lost circulation during drilling, an IFE Engineer was stationed on the rig, equipped with M-I SWACO proprietary VIRTUAL HYDRAULICS software with which to monitor the behavior of the fluid in the critical HTHP zones. The engineer used these specialized tools to optimize the performance of all fluid-related products and services. He also ensured that all benchmarking was carried out as planned and provided a comprehensive post-well report that identified areas for improved savings on future wells.

The Results

Using the IFE service allowed the operator to lower mud cost and rig time. By using an oil-base mud from below surface to TD, the operator saved four days' rig time, which, when combined with the savings in drilling fluid, resulted in a net savings of \$169,000.

The operator also improved drilling safety. Using VIRTUAL HYDRAULICS software played a major role in avoiding well-control incidents. Using the software, the IFE engineer was able to optimize tripping speeds and accurately predict downhole pressure in the HTHP zones, despite conditions that precluded downhole instrumentation. The VIRTUAL HYDRAULICS software allowed the engineer to constantly monitor rheological properties and densities downhole and allowed the critical HTHP zones to be drilled without incident.

This drilling program was carried out without environmental incidents in a very stringently monitored environment. The unique cuttings collection and disposal system enabled a large quantity of generated wastes to be transported to the injection site, slurried and re-injected without a single environmental incident.

The cross-functional expertise employed through the IFE service also aided in reducing drilling fluid losses to the formation. Earlier wells drilled in the Central Graben had encountered mud losses of up to 6,000 bbl. Using the pressure data acquired with VIRTUAL HYDRAULICS, the engineer was able to reduce mud losses to ± 500 bbl, which contributed to the reduction in overall drilling fluid costs.

The selected oil-base fluid contributed to improved rates of penetration (ROP). Faster drilling rates (up to 200 ft/hr) enabled the operator to cut rig time by four days, further reducing the operating costs.

The Details

Recognizing that the faster drilling rates attainable with an oil-base fluid system could only be realized with a radical change in waste collection and management, the IFE team developed a site-specific system to address environmental issues.

After analyzing the rig capabilities and calculating the volume of waste to be generated, the IFE team suggested a modified, vacuum-driven cuttings-handling system. Under this scenario, cuttings would be collected in special containers and shipped to the injection site. The new DuoVac containers, each with a capacity of 4.5 m³ and a maximum gross weight limit of 9.2 metric tons, were specially designed and built for the project. Six containers were installed in the containment area, with each one positioned on its own weigh station.

In addition, three 100-HP vacuum units and three vacuum tanks were installed on the rig. A specially fabricated collection trough was mounted beneath the cantilever. From here, the cuttings were conveyed by vacuum-assisted air flow through a spider arrangement of hoses into the DuoVac containers. As each was filled, it was lifted off the weigh station, replaced with an empty container and offloaded to one of two work boats constantly alongside the rig.

Once the surface hole was drilled, the oil-base portion of the well was begun.

The 16-in. section started at 1945 ft (593 m) and was drilled to 6400 ft (1951 m) in 49 hours, including connections. The 4455-ft section (1358-m) was drilled at an average ROP of 92 ft/hr (28 m/hr), with penetration rates rising as high as 200 ft/hr (61 m/hr). For the 16-in. section, 186 DuoVac tanks, each containing an average 2.9 metric tons of oily cuttings, were loaded and hauled to the platform for re-injection. That represents a total cuttings collection and disposal of 534.5 metric tons.

Early in the process of engineering the well plan, the IFE team examined formation data for the area and concluded that the possibility of well-control problems and lost circulation posed serious risks beginning in the lower part of the 12¼-in. section ($\pm 11,000$ ft [± 3353 m]). At that stage of the well, an IFE-designated, critical-well-analysis engineer was stationed on the rig to constantly monitor the fluid system. Using the proprietary VIRTUAL HYDRAULICS program, the engineer produced calculations that correlated very closely to those reported by the pressure-while-drilling (PWD) tool. The IFE engineer's data became even more strategic in the elevated temperatures and pressures in the 6½-in. section where no PWD tool could be used.

Throughout the lower 12¼-, 8 ½- and 6½-in. sections, the IFE engineer on the site reduced rheological properties of the mud system without affecting penetration rates, thereby optimizing the equivalent circulating density. Furthermore, yield-point and low-end readings were reduced below the programmed specifications, with no negative effect on hole cleaning. Despite the extremely narrow gradient, the well reached TD without a single well-control incident and at very cost-effective penetration rates.

The lessons learned in this original application promise to improve even more significantly the efficiencies and economics of future HTHP wells in the North Sea.

Questions? We'll be glad to answer them.

If you'd like to know more about the IFE service and how it's performing for our other customers, please call the M-I SWACO office nearest you.

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