As part of an extended reach field development program, a major operator required a horizontal water injector to be drilled to provide pressure support to nearby existing production wells.

During the planning phase, offset data revealed what to expect in the depleted reservoir sandstones. The main challenge was a potentially narrow margin between the equivalent circulating density (ECD) and fracture gradient when drilling the 8½-in. hole section. The ECD target set by the customer was 0.5 ppg below the minimum fracture gradient of 17.2 ppg, with a flow rate >500 gpm and a fluid density >12.4 ppg at 120-140°F BHST. Reliable pre-drill predictions on ECD were needed to best plan drilling operational parameters, and budget for the anticipated well time and materials.

Pre-planning simulations, in the proposed wellbore trajectory, required enhanced accuracy due to a true vertical depth (TVD) of 1,762 m (5,781 ft) and a maximum step out of 5,949 m to a measured depth (MD) of 10,230 m. Accurate ECD prediction at shallow TVD is challenging, and in combination with large measured depth, extremely accurate annulus pressure loss prediction would be critical to success.

The accurate prediction and balancing of contributing hydraulic effects within the wellbore are essential to being able to confidently design the well. These predictions are performed using standard inputs that are easily available pre-drill. Correction factors, or fine tuning of results, are not required to achieve the observed first-class accuracy; only a careful validation of input data is necessary to achieve a reliable match.

At a TVD of 1,762 m (5,781 ft), 0.1 lb/gal of ECD contribution is equal to 30 psi of annular pressure drop, compared to a well of 4,000 m TVD (13,124 ft), where 0.1 lb/gal of ECD contribution is equal to 68 psi. Using offset data from multiple operations, Halliburton Baroid’s Global Technical services and Research and Development teams collaborated, rapidly identifying areas where current physics and empirical-based model assumptions could be tailored for such ERD drilling scenarios.

Several factors affect the accuracy of any ECD prediction tool, including the pressure versus temperature behavior of the fluids rheology and density behavior when exposed to the temperatures and pressures experienced in the downhole environment. This requires accurate downhole temperature prediction in the dynamic drilling conditions to, in turn, predict the physical fluid properties, combined with accurate predictions on cuttings transport and pressure contributions of the drilled formation. This information can then be applied to specific wellbore geometry data to accurately predict pressure drop calculation in a changing, and often chaotic, downhole environment.
To improve on annular pressure drop predictions, further analysis of data from several ERD wells was performed, along with mathematical and physical models done in DFG drilling fluids graphics software. Refinements were made to modeling assumptions effecting pressure contributions of pipe rotation and eccentricity effects, and determination of the flow regime. These refinements resulted in improved accuracy of predicted annular pressure losses, allowing greater precision of ECD prediction. Using this advanced model, the appropriate rheology profile to drill the well was determined and a fluid system designed to achieve it.

RESULTS

The Halliburton Baroid team successfully utilized DFG hydraulics modeling software to accurately plan, model, and drill an extremely shallow, extended reach well. Project highlights are as follows:

» Determined what fluid properties were required to drill the well. The drilling fluid was designed to deliver the required ECD, while still maintaining maximum sag resistance due to the rheological ranges being properly established
» Monitored drilling and identified any areas of concern, in terms of hole cleaning and projecting ECDs to TD based on actual drilling fluid properties
» Validated DFG simulations via post-well analysis of PWD (pressure-while-drilling) data, reducing operator uncertainty with increased confidence in prediction accuracy
» Provided the most accurate DFG-generated prediction for annular pressure drop to date (never more than 30 psi of annular pressure loss difference from PWD) prediction for annular pressure drop to date (never more than 30 psi of annular pressure loss difference from PWD)
» Predicted ECD contributions of pipe rotation, pipe eccentricity, and flow regimes in this shallow, ultra-ERD well
» Performed hydraulic simulations, using DFG software, with higher level of accuracy than observed PWD
» Performed operations and completed drilling as planned and budgeted, without unexpected changes in drilling parameter

This chart highlights BARAECD® performance by mapping the DFG pre-well predicted ECD at varying flow rates against the observed PWD data.

ECD prediction ran with actual fluid properties and drilling parameters are plotted as red dots alongside the measured and pre-drill ECD values (black line).

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