Tampen planning gets concrete results

Planning for successful zonal isolation results in effective mud removal and ramped-up production.

In line with plans to systematically increase asset recovery this decade in Norway's mature oil-producing region of Tampen, Norsk Hydro engineers are revisiting high-profile wells in an attempt to ramp up production and recover a larger percentage of their investment.

The 10 platforms offshore Bergen represent combined investments by North Sea operators of about US $28.4 billion with an additional $4.6 billion planned for this decade. Only 22% of the estimated reserves on the Norwegian Continental Shelf have been produced.

Prior to extensive analysis of the Norsk Hydro wells, poor cement placement was perceived as the root cause of undesirable fluid channels. Using services based on novel procedures and engineering systems included in Schlumberger's Wellclean II Engineering Solution technology, wells ranging from highly deviated to completely horizontal were analyzed, causes of lower-than-expected flow identified and solutions determined.

Operator concerns about undesirable fluid channels resulting from poor cement placement were confirmed. Implementation of a new regime resulted in perhaps unprecedented cement bond quality in this region, meeting objectives of better high-quality cement placement and coverage throughout the production liners.

Integrity of cementing operations and complete mud removal are critical to achieving preferred zonal isolation and optimum flow of hydrocarbons.

The consequences of poor primary cementing jobs can be severe. Unwanted mud left in the annulus between casing and open hole causes sustained casing pressure and gas migration. Incomplete mud removal results in the costly risk of mud film or mud channels, allowing communication between subsurface zones or to the surface. Failure to separate fluids properly as they are pumped downhole can negate the most meticulous plans or the best designs and lead to ineffective mud removal or contamination that prevents cement from ever setting up.

Old challenge, new approach
New insights into displacement mechanics inside casing and in the annulus, combined with a structured fluids train approach, can improve primary cementing. Since effective mud removal cannot be achieved without considering the effect of all relevant parameters, innovative products and tools are used in combination to improve cement placement.

Designed to remove mud in deviated, extended-reach, horizontal and injection wells, the approach is based on preflushes to displace drilling fluids, chemical wash systems, custom spacers and a comprehensive software program and simulator. Team members use cementing design and evaluation software to evaluate all well parameters, including casing standoff, and recommend flow regimes, preflushes and volumes, and pump-rate sequences for preferred fluid displacement.

The two-dimensional, numerical simulator uses computational fluid dynamics physics to monitor cement placement. Using well geometry and trajectory, downhole fluid properties, volumes, pump rates and casing centralization, engineers predict the efficiency of mud removal and identify whether a mud channel will be left in place. Engineers then make necessary design changes to optimize the operation and achieve zonal isolation.

Bad cement coverage
Offshore wells drilled in the Tampen region vary from highly deviated to completely horizontal wells. Their highest pore pressure gradient measures about 0.55 psi/ft, and the lowest fracture gradient is about 0.72 psi/ft. Generally, the 8½-in. openhole sections are drilled with 12.1-lb/gal oil-based drilling fluids and are relatively gauged. Centralization programs call for one centralizer per joint throughout the 7-in. liner, yielding about 50% standoff.

After conditioning, the drilling fluid usually exhibits a viscosity of 27 cp, yield strength of 15 lb/100 sq ft and a 10-minute gel strength of 13 psi. Cementing
operations call for pumping about 60 bbl of base oil as a preflush followed by 130 bbl of spacer at 12.8 lb/gal and then conventional cement slurry with relatively low rheology at 14 lb/gal. After dropping the top plug, the displacement rate is around 2.5 bbl/min.

When engineers evaluated these wells after completion of cementing operations, poor cement coverage across production zones was clearly evident from UltraSonic Imager logs. Their concerns confirmed, Norsk Hydro engineers opted to use a new preflush system that included spacers formulated to leave a minimal impact on the environment. Properties of these spacers include lower toxicity, better biodegradation and lower bioaccumulation.

Cement simulator
Engineers used a fluid simulator, capable of dynamically displaying various displacement patterns and different fluid concentrations, to monitor the effects of changing parameters on the mud removal process. In addition, it identified the risk of leaving a mud channel behind the cement and calculated the percent of annular cement coverage (Figure 1). All simulator calculations were based on input data that included the well configuration, fluid properties, pipe centralization and pumping schedule.

Results depicted by the simulator agreed with the cement logs, indicating intermixing of fluids throughout the liner length in addition to low annular cement coverage. Based on this information, engineers began implementing major changes.

Altering critical parameters
The next cement operation was scheduled on a 90º horizontal well exhibiting similar conditions found in the earlier Tampen wells. One of the first parameters reviewed was the centralization program. Team members added additional centralizers at certain depths following analysis of running forces using a computer-aided design software module.

Since impact on the environment was a concern, environmentally compatible chemicals capable of superior or equal performance were needed. Engineers chose Mudpulse II spacer fluid because of its low impact on the environment, its effectiveness in displacing drilling fluids and its lower effect on cement thickening time and compressive strength development as compared to other available spacers.

The new spacer fluid enabled design engineers to fine-tune the various rheological properties independent of each other to formulate the most desirable spacer for displacing mud without channeling through it. It also had to be capable of being efficiently displaced by the cement.

The third change involved use of a high-solid-fraction cement system. Since the 7-in. liner was run in a completely horizontal section, engineers determined the viscous forces were more effective in displacing the mud than the gravity forces (the differences in fluid densities). In addition to possessing relatively high plastic viscosity, this lightweight cement system (14 lb/gal) possesses desirable set-cement properties including high compressive strength, low permeability and low porosity. Placement was simulated to prevent fracturing. Finally, crews pumped 300 bbl of fresh mud at a relatively lower density and rheology than the original well mud to dilute the original mud and break its gel strength.

Predicting and executing
Prior to actual pumping, designers simulated the modified design to determine if the changes would be adequate to improve mud removal. In addition to predicting cement coverage of greater than 95% over the majority of the production liner length, simulator data indicated pure cement coverage and a zero risk of leaving mud behind the cement (Figure 2).

Supported by the simulated data, the cementing operation was executed successfully as planned. During the evaluation process, the 7-in. liner was logged and results were impressive. The cement appeared to be of high quality over a substantial portion of the casing. Cement bonds of this quality had not been observed previously in the Tampen area. The cement log showed excellent bonding with no indication of any fluids channels throughout a large portion of the production liner.

Engineers have completed two additional wells in Tampen using this planning system with consistently successful outcomes. Two more applications are planned within the next few months. E&P

Figure 2. Prior to actual cementing operations, job design modifications were input into the simulator. The simulator predicted cement coverage of greater than 95% over the length of the production liner and zero risk of leaving mud behind the cement.