Underbalanced equipment meets challenges in MPD applications offshore Norway

By Tim Tønnessen, Halliburton; Bendik Larsen, Arnfinn Rønneberg, Statoil ASA

Figure 1: To deal with pressure control and lost circulation problems in the Gullfaks field, operator Statoil decided to pursue a solution that would include a full UBD-compliant, 4-phase separation package using clear brine as drilling fluid.

STATOIL AND HALLIBURTON introduced underbalanced drilling (UBD) technology to Norway in 2004 as a possible solution to drilling-related challenges that developed in the Gullfaks field when drilling into the caprock. Statoil, who operates this field, had experienced significant pressure control and lost circulation problems that resulted in the suspension of several wells during attempts to access reservoir targets. Drilling these wells with conventional means wasn't possible because of the small margin between pore pressure and fracture gradient.

After considering the different technologies available, the operator decided to pursue a solution that would include a full UBD-compliant, 4-phase separation package (Figure 1) using clear brine as drilling fluid. This decision was based on the assumption that in all probability, the produced fluid would be oil and/or gas. The brine density would be above 1.55sg in order to minimize surface pressure and risk for hole collapse.

Statoil Operating Company formed a team with Halliburton Underbalanced Applications to plan and complete the first underbalanced well offshore Norway. The first well, C-05A, was successfully drilled and completed in the summer of 2004 using both underbalanced and pressure-balanced techniques. Well C-09A was completed in the summer of 2005 and was the second managed pressure drilling (MPD) application in Norway where a fully underbalanced equipment set-up was used.

Following are some of the challenges faced and how valuable the system flexibility proved to be when quick changes were needed during the project.

Several important lessons were learned during the earlier well operations. These included operational-driven and cost-reducing measures such as changing out expensive brine with traditional solids-weighted mud systems. Since changes such as this impacted planning and equipment operation, these changes will be the primary focus throughout this document.

MPD AND UBD DESCRIPTION

In order to have a better understanding of the operational concepts as used in the context of this article, the authors wish to offer simplified description of the UBD and MPD operations referenced in this discussion to ensure that the Statoil operations are not misinterpreted in any way.

• MPD (or managed pressure drilling) focuses on solving drilling problems.

MPD uses, as one method, a surface choke and rotating control device in order to control bottomhole pressure. Moreover, all MPD projects must have appropriate equipment available that might be needed to handle any reservoir response and keep the well properly controlled.

• UBD (or underbalanced drilling) focuses on solving drilling problems and reservoir performance enhancement and characterization.

UBD requires the equipment mentioned above for MPD. Further instrumentation, gas injection and extensive separation capabilities also are required to handle produced formation fluids at surface in a controlled manner for continuous underbalanced applications.

It should also be noted that both techniques may be required for the same well, and this has been the case with certain Statoil wells.

BACKGROUND

Equipment had to comply with Statoil, **Norsok**, **Atex** and the other relevant European regulatory standards; therefore, close communication was maintained with the Norwegian authorities for all equipment strategies to ensure that the resulting solutions were in compliance with all relevant standards.

The first well, C-05A, was successfully drilled using heavy brine consisting of Potassium (K)-Format. The well configuration was an 8.5-in. sidetrack exiting from a junction whipstock set in 9⅝-in. casing. While drilling the well underbalanced as well as verifying it through a flow test, it was found that the produced fluid was primarily water. Continuing drilling underbalanced with a controlled influx would add more water to the active water-based drilling fluid system effectively decreasing the salt concentration and mud weight. Drilling the remainder of the well at balance without formation influx would eliminate produced water and keep the drilling fluid properties. This altered the project strategy while drilling the first well from full UBD mode to managed pressure drilling (MPD) mode in order to avoid thinning out the mud system and thereby increasing surface backpressure requirements.

By balancing the formation pressure throughout the last part of the well, further thinning of the rather expensive K-format brine was avoided. The liner was run and cemented successfully at balance, allowing access to drilling the reservoir conventionally.

The 2nd well, C-09A, was planned for a similar sidetrack to well C-05A. In addition, the work scope was expanded to include drilling the reservoir section at balanced pressure. Since the Gullfaks reservoir is very productive, with high permeability, near wellbore damage is not a significant consideration when evaluating drilling strategies. However, from the "lessons learned" from the first well and the fact that this was a highly productive reservoir with potential depleted reservoir zones, MPD appeared to be the most viable solution.

Since the engineering consensus was that the reservoir section could be drilled conventionally on well C-09A, Statoil felt that it would be a good candidate for testing the surface system's capabilities to apply MPD in the reservoir. This would pave the way for drilling more challenging reservoirs in the future. It would also allow the well to be completed if problems occurred while drilling at balance.

The base mud system was initially planned to be identical to that of the previous well as it was felt that this system would work while drilling the same type of formation. The start-up system would use the 1.55 sg K-Format with the contingency to add polymers and calcium carbonate to prevent losses in depleted sections. A detailed study had been carried out in advance to evaluate the potential use of the calcium carbonate weighted K-format brine with polymers as a contingency. Thus, a premix of this 1.67sg fluid was available on site.

Initially, this strategy was planned to minimize losses if significant pressure differential existed between the two reservoir targets due to depletion. Through lab testing, it was found that separation of oil would not be efficient within the available retention time. Other concerns were potential plugging of flow meters, choke control, weight material lost from the solids handling system, plugging of cuttings flushing system in the surface equipment.

SEPARATION EQUIPMENT

The key separation equipment used after the dual remote-operated choke manifold consists of two pressurized vertical separators and a pump skid. The normal capacities of the equipment are 35,000 bbl/day liquid, 1,800 bbl/day solids and 50 MMscf/day gas.

To aid the cuttings separation, clean drilling fluid is injected into the bottom cone rings where downward-angled nozzles flush cuttings down the cone (Figure 3). The resulting cuttings slurry is then pumped through a transfer pump up to the existing platform mud-processing module, located 26m vertically above the separator. The automated cuttings separation process is controlled by a mass flow meter to ensure stable levels in the vessel.

DRILLING OF WELL C-09A

The first section through the cap rock was drilled successfully in two runs with 1.55sg K-format and a targeted bottomhole pressure of 1,80 to 1.83 sg. The equivalent bottomhole pressure was initially started at the highest anticipated pore pressure (1.86sg) to minimize the risk for formation fluid influx. After drilling through the high pressure zone, the actual pore pressure was determined by bleeding off surface pressure in small controlled steps. The well pressure stabilized at 1.78sg, which was a lower pore pressure than initially expected. For the drilling, a rotary steerable assembly was used first. Failing to build enough angle, a bent housing motor assembly had to be run to ensure line up for the reservoir section. The open hole was then sealed off with a 7-in. liner and cemented at balance as per plan similar to the first well.

The cement and shoetrack were drilled using the premixed 1.67-sg fluid before displacing back to 1.54 sg K-format brine. When drilling the 6-in. hole, it became apparent that the formation was becoming increasingly unstable with time. This created problems cleaning the hole properly with the limited flow rate available.

Because of directional challenges and hole instability, drilling of the reservoir section took longer than planned. Several additional BHA trips took place, and attempts were made to continue drilling and clean hole with the viscous calcium carbonate-weighted K-format.

As noticed by several pack-off events, hole conditions deteriorated with time. Ultimately, it was decided to plug and abandon the first section, run a new whipstock higher up in the 7-in. liner, and conduct a new sidetrack attempt.

CHANGE TO OBM

To remove the uncertainty as to whether the mud was creating the problems, it was decided to go for a proven oil-based mud (OBM) system. Although not previously tested with the surface separation equipment, a quick design review identified no showstoppers. However, several concerns were flagged during the review, including:

- Barite could be lost through the cuttings removal process;
- Equipment wear issues;
- Failure of instrumentation;
- Plugging of strainers, jet nozzles, sample points and instrumentation;
- Cuttings could carry over to second stage and damage downstream pumps;
- High-friction forces due to more viscous mud;
- Gelling causing high pressure to break circulation and resulting high ECD;
- Need for recalibration of transfer pumps;
- Mud incompatibility with rubber seals, hoses and well control elements.

A detailed inspection was conducted offshore checking all critical elements between the surface system and the well. Subsequent to milling the new window, the well was displaced to OBM, and drilling commenced. After drilling a few meters, a hose burst between two pumps on the lower level of the rig used for transferring the drilling mud to the shaker. A careful inspection of all the platform hoses revealed that several hoses on the "transport" side to the shakers were old and in poor condition or of the wrong type to use with OBM.

The well was displaced to heavier OBM, and drilling was continued in a conventional mode while hoses were ordered and changed. Directional problems were encountered. Thus, an openhole sidetrack with a motor assembly was required to enable higher-angle doglegs. The hole condition seemed stable during this time.

As soon as all of the relevant hoses had been replaced, the well was displaced back to light (1.45sg) OBM, and drilling at balanced conditions commenced again. At this time, no problems were experienced on the surface side with regards to handling the OBM return flow and cuttings. The remaining drilling went without any surprises.

PRESSURE CONTROL

Figure 4 shows the result of choke control on the last part of the well using

Barite-weighted 1.45sg OBM. The pressure envelope for the reservoir drilling was fairly large; therefore, choke control was not critical. The bottomhole ECD varied in moments up to 0.05 sg (10 bar) with manual operation of the hydraulically actuated, remote-controlled chokes. This is approximately 0.01sg more deviation than was seen with the clean brine previously circulated.

Although partial plugging of the choke did occur, the choke was never completely plugged. The 3.5-in. chokes were very robust, and high-pressure strainers were not considered viable. A recommendation was made to link up the choke control monitoring to the rig pumps' shut down function in order to avoid fracturing of the formation in case of plugging of the choke(s). It was also noted that there were large fluctuations in bottomhole pressure when circulating the heavy OBM with the well open to surface.

OPERATIONS SUMMARY

All underbalanced flow, separation, and monitoring systems functioned according to specifications. No abnormal wear was detected due to the solids in the mud. Cuttings separation and handling systems were operating without issues. Nevertheless, as an added precaution, an additional strainer manifold was included for the third well to ensure "clean" fluid for the cuttings flushing system.

Implementation of MPD technology has allowed Statoil to drill previously abandoned wells that could not be drilled with conventional means. The success of the drilling of these wells has enabled the following best practices to be established:

- Cost effective solids-weighted mud, both water- and oil-based types, were verified to be viable for use with the underbalanced surface separation system that was initially designed for use with "clean" fluids;

- Choke control was verified to be within acceptable limits for this application. For projects where the difference between fracture gradient and pore pressure is minimal, an automated choke-control option should be considered;

- As a preventative measure based on the lessons learned, shut down activation and potential plugging of chokes has now been implemented to automatically shut off the mud pumps. This feature has been incorporated in the design for future wells in order to prevent fracturing the formation in such an instance;

- In rapidly changing project conditions, it is vital to conduct a detailed review of all systems in order to avoid incompatibility issues with drilling fluid — a situation that could cause problems both downhole and on surface.

The added flexibility that a pressurized separator-vessel set-up provided in this well cannot be measured. This experience has shown that use of this equipment can be invaluable when starting up MPD operations in any area where all reservoir parameters are not known. Many design requirements have now been determined from these initial wells to optimize future MPD units on the same field.

More information will be presented on this technology and the Gullfaks Field projects at the Galveston SPE/IADC MPD & UBO Conference & Exhibition, 28-29 March 2006. The presentation, "Solids Weighted Oil-based Mud & Underbalanced Surface Equipment Resolve Challenges in Managed Pressure Drilling Offshore Norway," has been developed by Tim Tønnessen, Halliburton, and Bendik Larsen and Arnfinn Rønneberg, Statoil ASA.