Comparison of reservoir knowledge, drilling benefits and economic advantages of UB, MP

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UNDERBALANCED AND managed pressure drilling may be effective solutions for overbalanced drilling problems, but the full benefit of these technologies can be realized only with better understanding of where each technique should be used and what benefits can be expected.

As the industry gains familiarity with underbalanced (UBD) and managed pressure drilling (MPD), the techniques have proven to be effective solutions to severe fluid losses and other problems inherent to conventional drilling. However, with better understanding of the basic concepts of each drilling method, their application can be optimized to yield significant additional benefits.

Generally, UBD is both a reservoir performance improvement and characterization tool, as well as a solution for tackling difficult drilling problems, while offering a unique well testing-while-drilling capability.

MPD, on the other hand, is a well construction enhancement tool, used primarily to address drilling-related problems that result in costly nonproductive time (NPT).

Given these generalities, there are well scenarios in which both techniques may be needed to provide different benefits in different hole sections of the same well.

Whether a full underbalanced program, managed pressure drilling or both are applied, in all cases maximum benefit is realized when program design is based on best practices for safely achieving specified project objectives in the most cost-effective way.

DEFINING UBD

While all drilling can be considered a form of "managed pressure drilling," since the pressure must be controlled or "managed" for safe drilling, the industry has adopted this terminology to specify certain drilling practices different from conventional overbalanced drilling. This has caused confusion because different interpretations can be made of what constitutes managed pressure drilling.

MPD equipment is seen rigged up on location in Southern Mexico, where clean-up times for wells drilled with MPD were reduced from 20 days to an average of 3 days and drilling time was cut in half compared with conventional OB wells.

A formal definition of UBD is as follows: "When the hydrostatic head of a drilling fluid is intentionally designed to be lower than the pressure in the formations being drilled, the operation is considered underbalanced drilling."

Whether the hydrostatic head is naturally less than formation pressure or induced, the underbalance condition is intended to allow influx of formation fluids that are circulated from the wellbore and controlled at surface. That means by definition, UBD provides the benefit of production during drilling — a fact that becomes a major factor in calculating comparative economics with other methods.

In addition, UBD allows comprehensive reservoir characterization while drilling, which may help reduce time and cost associated with conventional methods of gathering and analyzing well-test data, and which in some cases has led to discovery of previously unseen zones.

In terms of drilling benefits, reservoirs benefiting most from UBD are those formations prone to damage. These can include all types of formations, although significant benefits have been seen in naturally fractured reservoirs by minimizing damage to the micro-fractures and identifying fracture swarms. Additionally, UBD eliminates losses and differential sticking typically associated with OBD and can improve drilling efficiencies in hard rock or mature reservoirs.

In view of these benefits, UBD initially was only reluctantly adopted by the industry, with high equipment rental costs, regulatory limitations offshore, and unstable formations such as Gulf of Mexico being reasons most often cited for rejecting that option. By addressing those concerns specifically, MPD has emerged as an intermediary solution between underbalanced drilling and conventional overbalanced drilling.

WHAT IS MPD?

IADC has defined managed pressure drilling as "an adaptive drilling process used to precisely control the annular profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular pressure profile accordingly."

To describe the process, MPD is drilling with a controlled annulus and controlled returns to surface using an equivalent mud weight that is maintained at, or marginally above, formation pressure by manipulation of a dedicated choke device or other method. The key point is that reservoir fluid is not intended to reach the surface.

Rather, the primary purpose of managed pressure drilling is to enhance well construction by minimizing drilling problems, with reservoir benefits a secondary advantage. As a drilling solution, MPD can improve ROP and extend bit life, as well as minimize differential sticking and lost circulation. Capable of drilling narrow pressure margins efficiently and safely, MPD can reduce the number of casing strings required to access the target and allows full integration of MWD/LWD, directional, engineering and mudlogging services.

The critical difference between the two drilling methods lies in how well each can provide benefits for both drilling-related and reservoir/production-related problems.

Perhaps the single largest benefit of both techniques is how safe they are compared with conventional overbalanced drilling. As described below, both employ a closed pressure-controlled system, making them ideal for pressure control.

SURFACE EQUIPMENT REQUIREMENTS

Because both UBD and MPD provide means of controlling downhole pressures during drilling, as implemented in the industry, both techniques use the same type of equipment, and for both, surface equipment requirements and configurations vary widely.

System design set-ups range from simple wellhead rotating control devices (RCDs) to full equipment packages. Across the entire spectrum, a key consideration is safety and whether the equipment set-up controls the operation within strict safety limits.

In general, for UBD applications, key components of a complete surface equipment package where influx is expected and reservoir productivity is the primary objective includes:

- Upstream gas generation and fluid compression/injection systems.
- Wellhead RCD.
- Downstream choke-manifold system.
- Open or closed fluid-handling systems, including downstream fluid separation package (3-phase or 4-phase separation system).
- geologic sampler.
- emergency shutdown (ESD) systems.
- data acquisition and display systems.
- flow metering devices and pressure valves.
- rig-injection pumps.

Similarly, for MPD, requirements can range from a RCD tied to rig flow lines, to the comprehensive UBD-type equipment package listed above.

Several equipment set-ups can be derived from a combination of these key equipment components, with best practices driving design of the system most appropriate for safely handling the well. For example, where no or very minimal influx is anticipated, an MPD set-up may include only the RCD, with manual or automated choke control providing strict control of BHP within the pore pressure and fracture pressure operating window.

Where very narrow or inverse pore pressure/fracture gradients or fractures/permeable zones increase potential fluid influx, an MPD set-up may include downstream fluid separation equipment to safely process fluid within the pressurized system. Similarly, reservoir pressure and available mud system may dictate the need for a comprehensive UBD set-up that includes “all of the above” plus an upstream gas-generation and compression system. In these cases, UBD should be considered if technically feasible, because from an economics standpoint, there will be little cost difference since very similar equipment spreads are used.

Again, best practices will drive system design and dictate surface equipment required based on specific project objectives, as well as reservoir conditions.

WHICH TO USE AND HOW TO CHOOSE

While both underbalanced and managed pressure drilling provide means of controlling downhole pressures during drilling, the methods differ significantly in how they do it. During candidate well selection, the benefits and limitations of each technique must be considered qualitatively and quantitatively to determine which should be applied.

WELL SELECTION

In light of the main objectives identified at the start of the project, the selection process consists of analyzing geomechanical and petrophysical information to determine whether a particular well and/or reservoir is a potential candidate.

For a UBD candidate, preliminary wellbore-hydraulics modeling is performed to determine operational feasibility. That is, whether underbalanced conditions are possible and can be maintained through the entire hole section while providing adequate hole cleaning and satisfying downhole motor limits.

Since the primary driver for MPD is to resolve drilling problems, candidate selection is guided by whether MPD is capable of delivering the required results under the specific formation conditions. The process is the same as for UBD candidate selection; however, since no reservoir influx is expected with MPD, consideration of production potential is not as critical, except in cases where the system will be at-balance or potentially may be underbalanced in some sections of the open hole.

Once a prospect is identified, the optimal technique is selected and any potential production improvement is evaluated. (Currently, further investigation is required for quantification of production improvement potential of MPD.) Of primary importance in this evaluation are reservoir properties, which determine formation production and are input for reservoir modeling that estimates anticipated production during UBD. Different scenarios are modeled, and the results used in both detailed wellbore-hydraulics flow modeling and economics evaluation.

Final candidate qualification depends on the economic evaluation, as well as comparing other technologies such as stimulation. At this point, the importance of the quantified productivity improvement becomes apparent as various economic benefits are evaluated.

For example, both UBD and MPD techniques can significantly reduce fluid costs through use of lighter fluid systems and reduced mud losses. Both techniques require some level of surface system automation for rapid response to downhole conditions, and both require some form of data acquisition system, with costs dependent on the specific UBD or MPD equipment set-up necessary to obtain the required amount of data. Both have an effect on formation damage, where UBD can minimize or eliminate it, while MPD may reduce it compared with conventional drilling, which has long-term implications for improved productivity.

Utilizing MPD in non-reservoir sections may require a simpler equipment package to satisfy safety considerations for the well, reducing the dayrate compared with UBD. However, in many instances, the same equipment set-up is necessary for both methods, with the only difference being that smaller separation equipment may be used for MPD.

In some cases, MPD may not be capable of solving the problems encountered, such as when fracture pressure is too close to pore pressure, or when variations occur in pore and fracture pressures in different intervals within the same open hole. These cases may require well design to include UBD in some sections, and overbalance – including MPD – in others.

Thus, the selection process comes back to the primary objectives of the project – what needs to be accomplished to deliver specific benefits, and what equipment and data acquisition capabilities are required to do so.

CASE HISTORIES

With proper candidate selection, using these drilling techniques to meet the specific needs of a challenging drilling project can improve overall success and add tremendous value for the operator.

MPD – Mexico: In one application, formation clean-up times after wells were brought on production were reduced from 20 days for conventional OB wells to an average of 3 days for wells drilled with MPD, and drilling time was cut in half. The multi-well project in Southern Mexico was a deep, depleted, fractured and compartmentalized reservoir with widely variable pore pressures. The main objective was to design a flexible system to cover pressure gradients ranging from 2 to 8.34 ppg, minimizing overbalance because of the narrow margin between pore and fracture pressures, and to reduce or eliminate drilling problems of differential sticking and lost circulation.

BHP was controlled through precise selection of critical operating parameters, such as injection flow rates, fluid properties and chemical injection control. During MPD, important variables were measured, recorded and displayed at the rig site and/or transmitted to other locations, allowing remote monitoring and real-time adjustments to maintain the narrow target BHP.

Successful implementation of MPD in this case included process improvements from lessons learned while drilling challenging hole sections under changing conditions, as well as increased ROP despite controlled drilling for hole cleaning. MPD times were approximately half those of offset conventional OBD wells, and when the MPD wells were brought on for production, cleanup times were reduced by 15%.

UBD – East Asia: When a severe loss zone prevented conventional drilling from accessing the reservoir in several onshore East Asia wells, UBD was successfully employed to achieve two goals. First, it solved drilling problems by maintaining underbalanced pressure control to minimize losses while drilling to TD. Second, it minimized reservoir damage and evaluated productivity of different intervals. This included characterizing properties from flow testing and determining production sustainability and any need for stimulation.

This application required high-end data acquisition, using PWD and additional downhole memory gauges for controlling BHP. In some wells, two types of gas meters were used to allow constant monitoring of the gas rate. Data were transmitted via satellite to the service company's reservoir evaluation center, where analysis was carried out in real time, including periodic flow tests and pressure build-ups in some wells.

In this case, successful UBD made it possible to drill into the reservoir without losses, although some wells did not reach TD when unexpectedly high production made further drilling unfeasible without going overbalanced and causing formation damage, or the surface and rig equipment limits were reached.

Compared with conventional overbalanced drilling in this application, UBD reduced NPT by 75% through elimination of time associated with controlling losses, kicks, stuck pipe and improved well control. In addition, bit requirements for the high compressive strength rock were reduced to just two or three bits, compared with six to eight bits typically required for overbalanced drilling.

Because the formation was extremely sensitive to damage even with limited short periods of overbalance, MPD would not likely have yielded the productivity improvements observed.

UBD also provided reservoir characterization for the application, confirming reserves and further delineating reservoir properties of production intervals, including confirming at least one zone previously thought to be not productive.

However, in this case the greatest benefit of UBD was realized in a ten-fold production increase compared with the sustained offset OB wells, and a five-fold increase compared with the best performance of stimulated wells in this and offset fields.

Stimulation was not necessary, providing additional cost savings from UBD, and long-term production tests reveal little decline in the sustained production.

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