Use of underbalanced drilling technology expands

UNDERBALANCED DRILLING has emerged as a critical technology that could bring significant gains in drilling efficiency.

IADC members recognize the potential of underbalanced drilling technology and have formed the Underbalanced Operations Committee to promote the safe and efficient use of the technique.

A number of projects are underway by the Committee, including the development of a standard well classification system and supporting nomenclature.

A session, “Underbalanced Well Operations and Engineering,” is a part of the 2001 SPE/IADC Drilling Conference. Papers prepared for this session, to be chaired by **D Heeman**, **Tesco Drilling Technology** and **J Boyle**, **Weatherford**, focus on safety, well planning, reservoir characterization, pressure prediction, and other critical areas.

MOVING UBD OFFSHORE

In 1996, a multidisciplinary team in **Shell Expro**’s Gas Supply Group began a project to adapt existing onshore underbalanced drilling technology to the North Sea offshore environment. Using an evolutionary stepwise implementation path, the technology was matured from low-head drilling operations in 1997 to two fully underbalanced drilling strings at present.

In SPE/IADC paper 67688 prepared for the Conference, **J Kohnert**, **Shell UK Exploration and Production** highlights the safety critical learning that emerged during the project. The paper, “Safety Critical Learning in Underbalanced Well Operations in Shell Expro,” focuses on:

- The team structure and implementation plan;
- Mud and nitrogen system;
- BOP and snubbing unit;
- Pressured flow line and separator package;
- UBD well design.

OFFSHORE INDONESIA

Repsol-YPF-MAXUS Southeast Sumatra B V decided to implement underbalanced drilling technology in the development drilling campaign in the Krisna Field offshore Indonesia. The target production zone is fractured carbonate. Previous wells drilled in this concession have had massive losses of drilling fluids once the productive zone is encountered. The zone also has a very high clay content, which may be prone to fluid damage.

In SPE/IADC paper 67689 prepared for the Drilling Conference, **G Soerdasono**, YPF-Maxus Southeast Sumatra; **P R Brand**, **Blade Energy Partners**; and **B Allison**, **Northland Energy Services** present the pre-engineering, project management and field implementation results for the drilling of the Krisna D12. “Planning and Implementation of the Repsol-YPF-Maxus Krisna Underbalanced Drilling Project” describes the first use of the technology offshore in the region.

This underbalanced equipment layout on the R&B Falcon Roger Mowell was used for the first UBD project from a jackup in South East Asia.

In an effort to eliminate lost return, eliminate stuck pipe, identify fractures and eliminate formation damage, Maxus decided to proceed with the Krisna underbalanced drilling project.

Since it was the first attempt of underbalanced drilling in Southeast Asia from an offshore unit, significant planning and engineering were required.

The Krisna D12 production interval was successfully drilled underbalanced from 10-20 June, 2000 from the **R & B Falcon** jackup Roger W Mowell.

A total of 1,159 ft of formation was drilled underbalanced without any significant drilling related problems.

The well was TD’d before reaching the proposed total depth because the basement high was encountered. There were no instances of lost returns or stuck pipe once the well was in an underbalanced condition.

Although the project encountered problems during the initial start up, modifications to the system and changing the fluid system to a diesel mist eliminated the majority of the issues.

By the end of the well, the underbalanced system was working well, the authors report.

PROFILING PRESSURES

Understanding reservoir characteristics is a key to successful underbalanced drilling operations.

In SPE/IADC paper 67690 prepared for the Drilling Conference, author **W**

Kneissl, **Schlumberger Cambridge Research**, describes a method for deriving both pore pressure and permeability profiles of a reservoir in real time—on a foot-by-foot basis—during underbalanced drilling operations.

Such information about near wellbore characteristics of the reservoir offer invaluable input into drilling and completion decisions.

The algorithm described in the paper, "Reservoir Characterisation Whilst Underbalanced Drilling," can be run at the well site with a laptop computer and has been extensively tested against real UBD data, according to the author.

The mathematical methodology presented is an extension of that described in earlier papers, but the new algorithm also determines local pore pressure values, which allows for a more accurate description of the local drawdown, and thereby a more accurate derivation of the permeability than has previously been possible.

Indeed, says the author, previous work along these lines would misinterpret higher pore pressure regions of the reservoir as higher permeability zones.

The author also discusses the implications of compressibility in the muds used during underbalanced drilling for the extrapolation of flow rates measured at surface to production rates downhole.

This is a critical factor in accurate characterization of the reservoir, since it is the local production rates downhole that are used to characterize the response of the reservoir to the drawdown condition.

FOAM SYSTEM

An extensive experimental program developed at **Petrobras R&D Center** as part of the joint industry project (JIP) named "Lightweight Fluid Drilling from Floating Platforms," is summarized in SPE/IADC paper 67691. "Foam Rheology Characterization as a Tool for Predicting Wellbore Pressures While Drilling Offshore Wells in Underbalanced Conditions," prepared by **A L Martins**, **A M F Lourenço**, and **V Silva Jr**, Petrobras, discusses procedures and results.

The lab work steps included foaming agent selection (considering optimum concentration and salt/oil contaminants), rheology lab equipment development or adaptation and a definition of test procedure and matrix.

Based on a set of real scale tests under foam circulation conditions and numerical simulations, the authors propose a comprehensive model for predicting borehole pressures while drilling underbalanced or near balance with foams.

The use of foam is a highly attractive alternative for drilling depleted, lost circulation or gas zones. Due to its complexity, however, a foamed system requires special attention while designing field operations.

The main goal of the project is to make it possible to drill with foam from floating platforms.

After about 60 rheology tests performed in lab and pilot scale equipment, correlations were proposed to predict rheological parameters as functions of foam quality.

Based on the experimental data, a set of correlations was developed to predict foam rheological properties as functions of base fluid rheological properties and foam quality. The next step was to evaluate the lab results by comparing pressure predictions with experimental data obtained by circulating different quality foams in a real scale vertical well located at the Petrobras Training Center.

The proper fitting of the proposed model and the experimental results supported its implementation in Petrobras lightweight fluid drilling software.

The authors suggest the possibility of applying the technique in deepwater conditions will open a new strategy for the development of depleted areas in offshore fields worldwide.

Proper knowledge of downhole pressures is important for adequate system design and operation.

AERATED MUD

Predicting flow patterns in directional wells is always important. But the use of aerated muds poses special challenges.

Alternate SPE/IADC paper 67189, "New Developments in Aerated Mud Hydraulics for Drilling in Inclined Wells," describes a study to determine the hydraulics of aerated mud in an inclined annulus.

The paper was prepared for the Drilling Conference by **Ashwin Sunthankar**, **Ergun Kuru** and **Stefan Z. Miska**, **The University of Tulsa**; and **Arjan Kamp**, **PDVSA/Intevep**.

When drilling with aerated drilling fluids, bottomhole pressure is a strong function of gas-liquid flow patterns. The existing methods of predicting flow patterns are mostly based on the extrapolation of results from pipe flow to flow in annuli.

Due to non-linear relationships between flow rate, pipe size and pressure drop, this practice may not be appropriate to apply in drilling operations, according to the authors.

To verify the applicability of existing practice, the study described by the authors focuses on hydraulics of aerated drilling fluid flow through an inclined annulus, typical for drilling operations in directional wells.

Extensive experiments were performed in a unique field-scale low-pressure flow loop (8-in. x 4.5-in. annular geometry, 90 ft long) in inclined positions (15°, 45° from vertical) with and without drill pipe rotation.

The liquids used were water and aqueous polymer solution (CMC+XCD+water) at flow rates in the range of 100-325 gpm and air in the range of 8-85 scfm.

Gas/liquid ratios are chosen to simulate the exact gas/liquid ratios under downhole conditions, correcting for the fact that the actual pressure in the flow loop is much lower than the bottomhole conditions.

Pressure drop and average liquid holdup over the entire annular section were measured. The authors report that they are not aware that such data has been published before.

The two-phase flow patterns were identified by visual observations. Bubbly flow and slug flow are the two flow patterns observed over the ranges of the chosen test matrix. The presence of slug flow does not justify many of the existing field and simulation practices that assume homogeneous gas-liquid flow.

Also, the flow pattern boundaries were shifted compared to pipe flow. The transition between bubbly flow and slug flow (for 15° inclination) was observed at a void fraction of 0.32 as compared to that reported for pipe flow of 0.25.

But for air-aqueous polymer fluid flow, it was the same as for air-water pipe flow (0.25).

For flow with drill pipe rotation, churn flow was observed instead of slug flow due to the churning of slugs by the rotating drill pipe. The authors report that there was no significant effect of drill pipe rotation on the pressure drop for air-water flow, while the pressure drop decreased in case of air-aqueous polymer fluid flow with drill pipe rotation.

A higher pressure drop was observed in case of air-aqueous polymer fluid flow compared to air-water flow.

An existing unified pipe flow model was modified based on the experimental results and was evaluated against experimental and field data.

The comparison shows that the pressure drop prediction by the modified model for inclined wells is better than some other existing models, though it still under-predicts the experimental pressure drop measurements.

REAL TIME SUPPORT

A successful underbalanced drilling operation requires control of downhole pressures and management of the fluids flowing from the well. Downhole pressures and the amount of fluid flowing out of the well are affected by injection of fluids, reservoir inflow performance and operational procedures.

These parameters are inevitably subject to fluctuations that cause transient responses to the multiphase system.

In Alternate SPE/IADC paper 67693, "Underbalanced Drilling: Real Time Data Interpretation and Decision Support," the authors describe a model used to predict these changes. The paper was prepared for the Drilling Conference by **R J Lorentzen** and **E H Vefring**, **RF-Rogaland Research**; **C V M Lage**, **Petrobras**; and **K-K Fjelde**, **RF-Rogaland Research**.

During an underbalanced drilling operation several parameters like injection rates, downhole pressure, choke pressure and outlet rates can be measured. Methodology has been developed for incorporating the measured data in a transient model.

The transient model is continuously updated with the measured data. The idea is to estimate the different parameters in the multiphase model and the reservoir model to give a correct interpretation of the conditions in the well.

Based on this interpretation, the future state of the underbalanced drilling system can be predicted.

The model can be used to predict the consequences of change in the underbalanced drilling system such as connections and shut down.

The methodology has been applied to measured data from a 1,300 m deep well. Several transient cases have been considered with drill string injection and parasite string injection. ■