Coiled tubing underbalanced drilling may increase production at Lisburne Field, Alaska

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To improve productivity in the Lisburne Field, a project was implemented using underbalanced drilling for multilateral wells. To minimize the surface kit size in the harsh environment, the project used locally available separator and heater packages (seen above). A skid was manufactured to control the gas lift gas injection rate (left).

IN 2005, BP **Alaska** began evaluating the application of underbalance drilling technology as a method for drilling multilateral wells in the Lisburne Field. The evaluation process was enacted as a response to three key challenges at Lisburne:

1. Slow ROP through the Wahoo's hard carbonate formation.

2. Frequent total losses of drilling fluid when drilling conventionally.

3. Poor understanding of the orientation, frequency and impact of fractures on production.

The main objective of implementing underbalance technology in the Lisburne Field was productivity improvement. This was to be realized by improving ROP, thereby allowing for long laterals to be drilled, intersecting more fractures. Coiled tubing underbalanced drilling (CT-UBD) would also allow for drilling multilaterals from a single parent wellbore through the production tubing. In addition, it was felt that underbalanced drilling would eliminate losses to the formation, with a side benefit of potentially mitigating formation damage.

A 2-well, 5 lateral pilot project was approved. A coiled tubing drilling rig was adapted for use in an underbalanced drilling mode. The pilot was completed during summer 2006 with excellent HSE performance. Although not without operational problems, the project demonstrated that underbalanced drilling could be used to increase rate of penetration and bit life. The pilot also demonstrated that underbalanced drilling could eliminate many of the hole problems associated with conventional drilling, making the drilling of long reach multilaterals feasible.

INTRODUCTION

The Lisburne carbonate reservoir has approximately 2 billion bbl of OOIP. The Wahoo formation, at a depth of about 8,900 ft (TVDSS), is tight, fairly thick (400 ft) and highly consolidated, with thin interbedded mudstones layers. Reservoir fluid is mainly oil with a gas cap covering a portion of the field.

Previous drilling in the reservoir had been done overbalanced. Problems included low ROP (averaging about 105 ft/day) and instability of the mudstone layers in water-base muds. Production performance of the reservoir had been disappointing, with an oil recovery to date of 8% due to low matrix permeability and excessive gas production.

Overbalanced drilling and conventional stimulation techniques have had mixed results. This led BP to consider underbalanced drilling. The idea was to place multiple laterals from a single parent wellbore within the carbonate sections underbalanced, thus increasing exposure to fractures and avoiding the potentially unstable mudstones. The main motivation for UBD was ROP improvement and elimination of drilling problems associated with overbalanced operations. Other potential benefits included improved productivity and reservoir characterization.

ENGINEERING, DESIGN

The planning phase of the project encompassed four primary segments:

- Feasibility study.
- Candidate selection.
- Detailed well planning.
- Hazard analysis.

CANDIDATE SELECTION

All wells went through a rigorous selection criteria, which consisted of:

1. Minimal remaining economic potential for the parent well.

2. BHP greater than 3,300 psi.

3. Undeveloped target present with significant resource potential.

4. Top of structure much deeper than anticipated base of gas.

DETAILED WELL PLANNING

To eliminate the concern over hole cleaning, problems below the tubing packer (in the 7 in.), and to give a higher probability of isolating the parent wellbore perforations, the decision was to work over the wells and create a 4 ½-in. monobore completion.

The wells were designed to use 2-in. coil and drill 3-in. bi-center hole. Diesel was selected as the power fluid to minimize potential problems with the mud stones. Field natural gas injected through the gas lift system was designed as the lift gas.

The directional plans were developed to miss troublesome mudstone sections.

If it was not possible to miss the mudstones, the well was design to cut the mudstones at inclinations less than 70° or greater than 107° (avoid being near horizontal in the mudstones).

EQUIPMENT SELECTION

To minimize surface kit size in the harsh cold weather environment of the North Slope, a locally available portable test separator was used for the Lisburne CT-UBD project. Additional equipment included diesel storage tanks and a heater to mitigate hydrate and emulsion potential problems.

The diesel was stored in four 400-bbl upright tanks. The tank farm came complete with transfer pumps and chemical injection pumps.

GAS CONTROL SKID

To control the gas lift gas injection rate, a gas control skid was manufactured. This skid utilized a PLC system to allow the desired rate to be remotely controlled.

EQUIPMENT LAYOUT

The equipment layout was controlled by the hazardous areas constraints adopted for the project. A zone 2 area, defined as a 60-ft radius around each of the wells, had restricted access. A further 150-ft zone was defined around the well that was being drilled. This area was to be clear of any potential ignition sources.

The view of the layout on the first well can be seen in Figure 6.

HAZARD ANALYSIS

The process of hazard identification and hazard mitigation was broken into several steps for the Lisburne CT-UBD project:

1. Preliminary Hazard Identification study (HAZid) was designed to identify the initial level project hazards.

2. A two-day detailed HAZid was conducted at the well site to further identify project hazards and categorize each one by probability of failure and risk.

3. A two-day detailed Hazard and Operability Analysis (HAZop) was conducted in April.

4. A detailed procedural review and procedural HAZop was conducted.

5. A Risk Register detailing the risk and mitigations was constructed.

6. Peer review of operations was conducted with UBD and coil experts from within BP and its partners.

7. A Drilling Well on Paper (DWOP) was conducted in June.

8. Multiple on-site audits were conducted.

9. Authorization to Proceed (ATP) was conducted and given on 21 June 2006.

TRAINING

There were three levels of training given for the Lisburne project:

1. Scenario training for all critical decision-makers.

2. Project orientation training for all field personnel.

3. Live gas training for the rig crews.

IMPLEMENTATION

The implementation phase of the project was broken down into the workover phase and the drilling phase.

WORKOVER PHASE

The two wells were worked over in batch mode. The production tubing was pulled, and the original perforations were cemented. The new monobore completion consisted of a 4 ½-in. scab liner and 4 ½-in. production tubing. The production tubing included a TRSCSSV at 2,000 ft and gas-lift mandrels.

DRILLING PHASE — FIRST WELL - LATERAL #1

Final live gas rig training was done for all crews prior to milling the casing for the first lateral. Once competency of the crews was assured, the first window was milled at 10,732-ft MD, and underbalanced drilling commenced. As planned, drilling started with a 2% KCL fluid to mitigate risk until the crews gained comfort in the operations. Similarly, the well was killed for the first trip (all subsequent trips were done live using pressure deployment/un-deployment techniques).

After the crews gained confidence, the fluid system was switched to diesel. Problems with weight transfer to the bit were overcome by experimenting with additions of drag-reducing agents and utilizing an agitator. Drilling parameters ranged from 1.5 bpm to 1.7 bpm with gas injection rates ranging from 3 MMSCF/d to 4 MMSCF/d and a drilling BHP of approximately 3,200 psi (about 300 psi underbalance to static reservoir pressure). Production rates between 0.3 and 0.5 bpm were noted while drilling.

The lateral reached a planned total depth of 12,800 ft. The well was tested prior to setting the whipstock for drilling the next leg. Following the flow test, significant paraffin was noted on the pipe. Several runs were required to clear the wellbore of paraffin prior to proceeding.

FIRST WELL - LATERAL #2

The second lateral was drilled from 10,707 ft to a total depth of 12,532 ft. Initial conditions were 1.7 bpm diesel with 3 MMSCF/d of lift gas for a BHP of 2,900 psi. Lift gas was turned off on this lateral when production was sufficient to achieve underbalanced conditions without the aid of lift gas. The well was tested at TD. Paraffin problems occurred again following the flow test causing additional lost time.

SECOND WELL – LATERAL #1

The rig was moved over the second well. The whipstock was set and the window milled. The lateral was drilled from 9,907 ft to a planned depth of 10,875 ft. Injection rates were between 1.5 bpm and 1.7 bpm with gas rates between 3.5 MMSCF/d and 4.5 MMSCF/d for a BHP between 2,800 psi and 3,300 psi. The lateral was flow tested, and the well was prepared for the next lateral.

SECOND WELL – LATERAL #2

Due to problems not associated with this project, the source of diesel was lost. The decision was made to continue with the project using a 2% KCL brine as the drilling fluid. The second lateral was drilled from 8,960 ft to 9,748 ft. Injection rates ranged from 1.6 bpm liquid to 1.7 bpm with gas injection rates from 4.0 MMSCF/d to 4.5 MMSCF/d for a BHP between 2,850 psi and 3,350 psi.

Following a trip for a BHA change, it was not possible to pass a mudstone at 9,408 ft. Multiple attempts to pass the mudstone failed. The decision was made to abandon this lateral and sidetrack to avoid the problem zone.

OPEN HOLE SIDETRACK

An open hole sidetrack was performed at 9,260 ft. The lateral was drilled to 9,370 ft. After a wiper trip to the window, it was found that the bit would not pass a mudstone previously drilled at 9,122 ft.

The decision was made to abandon the lateral and move up the hole.

SECOND WELL – LATERAL #3

A new window was cut higher in the well to avoid the troublesome mudstone. The final lateral was drilled from 8,936 ft to 11,500 ft. Injection rates ranged from 1.5 bpm liquid to 1.7 bpm with gas injection rates from 4.0 MMSCF/d to 4.5 MMSCF/d for a BHP between 2,850 psi and 3,350 psi. Gas injected was stopped when contribution from a fracture at 10,300 ft allowed underbalanced conditions to be maintained without injection.

RESULTS

The rig team achieved zero incidents. Outstanding execution of the 2 well, 5 lateral pilot project included:

• Total of 9,130 ft drilled in 5 laterals. Remarkable bit runs of 780 ft, 832 ft and 977 ft MD, all of which were Lisburne coiled tubing drilling (CTD) records. Most footage in one day (666 ft) and longest CTD Lisburne lateral of 2,564 ft MD (984 ft longer than any previous overbalance drilled lateral).

• Average ROP of 239 ft/day in first well and 286 ft /day in second well, double previous ROPs in overbalance drilled wells.

• Over 40 safe pressure deployments of the 65-ft long drilling bottomhole assembly into 700 to 1,000 psi wellhead pressure wellbores.

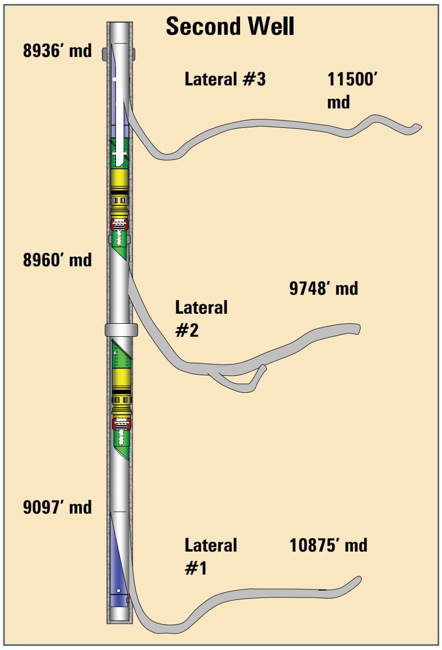
• Five flawless dual string 4 ½-in. scab liner and 7-in. liner window exists.

• Produced 14,000 bbl of oil from the reservoir while drilling the laterals.

• The pilot project was completed in 113 days and about 40% over budget. Significant learnings from the trouble times were achieved.

CONCLUSIONS

The Lisburne CT-UBD trial demonstrated that underbalanced drilling could be successfully implemented while meeting the North Slope's strict environmental and safety standards. No safety incidents occurred. This technology may help deliver additional oil resources from the Lisburne field.



In the 2nd well, 3 laterals were drilled at an average ROP of 286 ft/day — double previous ROPs in overbalance-drilled wells.

REFERENCES

1. Suryanarayana, P. V. et. al., "Basis of Design for Coiled Tubing Underbalanced Thru-Tubing Drilling in the Sajaa Field", SPE 87146, IADC/SPE Drilling Conference, Dallas, Texas, March 2004.

2. Biswas, D., Suryanarayana, P. V., Frink, P. J., Rahman, S., "An Improved Model to Predict Reservoir Characteristics During Underbalanced Drilling," SPE 84176, SPE Annual Technical Conference and Exhibition, Denver, Colo., October 2003.

3. Hunt, J.L. and S. Rester: "Multilayer Reservoir Model Enables More Complete Reservoir Characterization During Underbalanced Drilling," IADC/SPE 81638, Underbalanced Technology Conference and Exhibition, Houston, Texas, March 2003.

4. Vefring, E. H. et al.: "Reservoir Characterization During Underbalanced Drilling: Methodology, Accuracy, and Necessary Data," SPE 77530, Annual Technical Conference and Exhibition, San Antonio, Texas, September 2002.

5. Medeiros, R. S., Biswas, D. and Suryanarayana, P. V., " Impact of Thief Zone Identification and Shut-off on Water Production in the Nimr Field," SPE/IADC 91655, 2004 SPE/IADC Underbalanced Technology Conference and Exhibition Houston, Texas, October 2004

6. Suryanarayana, P. V., Kennedy, Vaidya, R. N., and Wind, J., "Use of a New Rate-Integral Productivity Index in Interpretation of Underbalanced Drilling Data for Reservoir Characterization," SPE 106756, Production Operations Symposium, March-April 2007.

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