Horizontal UB well in Libya multiplies production

THE SABAH G-55 well was the first underbalanced horizontal well to be drilled in Libya. The targeted formation is a mature reservoir that has been substantially depleted to a current estimated pressure of 1,050 psi from an original reservoir pressure of 2,256 psi. The producing formation consists of 2 main reservoir zones – Zone I and Zone II – separated by a low porosity tight zone layer. Zone I is made up of dolomite, and Zone II is made up of limestone with good porosity development, often up to 35%. Abundant fracturing is evidenced by mud losses while drilling, FMI, dipmeter, core description, pressure transient analysis and production performance.

OBJECTIVES

The underbalanced drilling project aimed to achieve 6 goals:

•To drill the horizontal reservoir section from 5,961 MD to TD at 7,628 ft MD;

•To eliminate or minimize lost circulation so that no drilling time is lost curing losses or associated with drilling problems;

•To minimize formation damage caused by the loss of conventional drilling fluids to the formation – as occurred on previous wells drilled overbalanced in the field – by maintaining underbalanced conditions in the reservoir;

•To improve production rate and enhance recovery;

•To evaluate and characterize the reservoir rock as well as the production rates along the well path while drilling underbalanced;

•To increase the rate of penetration above that of the penetration rates measured while drilling offset wells overbalanced.

OPERATIONAL OVERVIEW

The top hole section of the Sabah G-55 NC74F horizontal well was drilled conventionally and cased with a $9\frac{5}{8}$-in. casing to 5,011 ft MD. A 6-in. horizontal wellbore was drilled in the reservoir with a 2-phase nitrified Sabah crude oil mixture to a total depth of 7,331 ft MD (5,465 ft TVD) with 2 motors and 2 bits. The directional bottomhole assembly consisted of a 6-in. polycrystalline diamond compact bit, a 4 ¾-in. positive displacement motor (PDM having a 1.5° bent housing) with a tapered drillstring consisting of a 5-in. drillpipe, above the 7-in. liner and 3.5-in. drillpipe and heavyweight drillpipe in the liner and open hole. An EM-MWD (E-Pulse) and a gamma ray tool were incorporated in the bottomhole assembly for survey telemetry, real-time bottomhole pressure and to provide information for geo-steering.

The Sabah G-55 was drilled using conventional jointed pipe with the drillstring injection underbalanced drilling technique – meaning the nitrogen and the Sabah native crude were injected into the drillstring. Detailed operational and engineering procedures were put in place to ensure constant steady-rate bottomhole circulation pressures necessary to minimize pressure transients often associated with 2-phase circulation systems.

MULTIPHASE FLOW

A multiphase flow hydraulic envelope was used to determine the required liquid and gas injection parameters to ensure continuous underbalanced drilling conditions. Hydraulic simulations were carried out considering the worst-case scenario and no well production. The operational hydraulic envelope was created at the proposed final well depth (TD) and was defined between maximum and minimum operational conditions, such as the maximum flow rate that can be used for the downhole motor and minimum horizontal fluid velocity for guarantee the hole cleaning (210 ft/min).

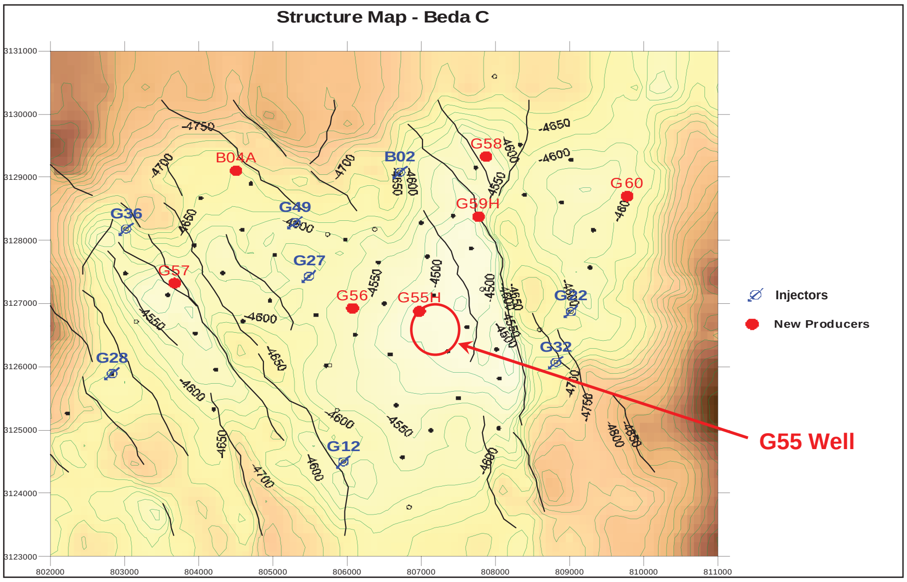
However, the actual operating area was slightly different from that of the recommended envelope because of the increased production from the wellbore, the long connection times due to the changing of the rotating control head elements and the accuracy of the data used to perform the modeling.

IN COMPARISON

Well G-53 was the first horizontal well drilled in the Sabah field. It was a re-entry well planned to penetrate layer B1 of Beda "C" formation with a 6-in. horizontal hole of 1,500 ft in length. However, due to the severe losses encountered while drilling in Beda "C," the decision was made to TD the well at approximately 580 ft of horizontal drain section. Well G-53 was put on production in September 2000, with a production rate of about 200 bbl/day. In comparison, Well G-46 was a vertical well perforated in layer B1 only, with a production rate of about 160 bbl/day.

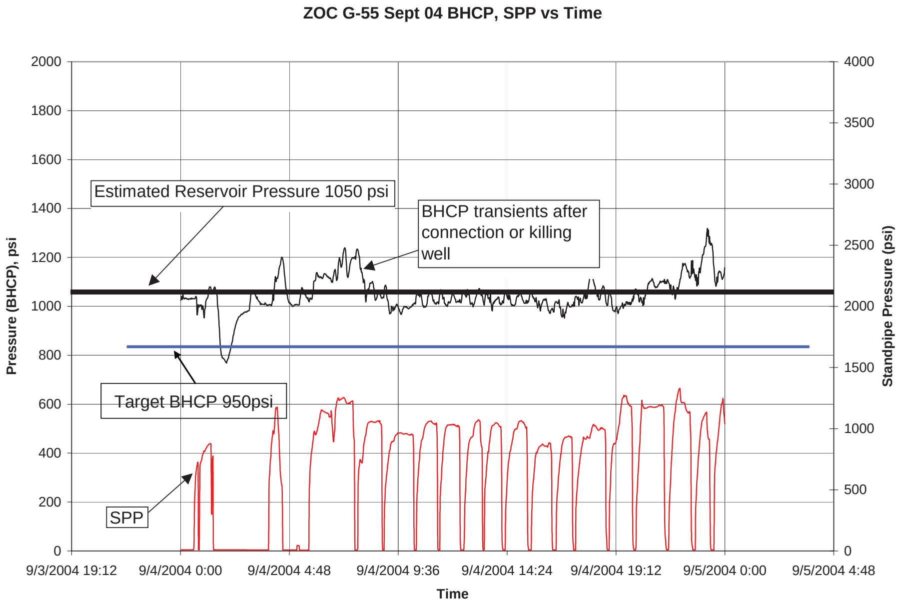
Well G-55 was the first well in Libya drilled with underbalanced technology. It penetrated layer B1 with a 6-in. horizontal hole and a lateral length of 1,353 ft. It was put on stream in October 2004. Initial production on the G-55 was 600 bbl/day of oil, which stabilized at approximately 450 bbl/day.

Sabah G55 UBD Well location



A comparison of the above 3 wells indicates that the production from the G-55 well is nearly 3 times that of the vertical well and more than double that of the horizontal conventional well, even though they produce from the same layer and in the same area.

Underbalanced drilling problems



PROBLEMS

When annular slugging occurs, higher-than-planned bottomhole pressures are created, which leads to a cycle of production gains followed by drilling fluid losses to the reservoir. The high frequency of changing the rotating control diverter sealing elements was directly related to the identification ring grooves on the drillpipe used, in addition to the poor stack alignment of the derrick with the BOP stack caused the RCD elements to be cut during any drillpipe movement.

The underbalanced drilling data acquisition system was unable to receive data from the rig, Therefore, accurate reservoir characterization couldn't be performed.

Because it was not possible to hang a 7-in. tieback liner from surface, the annular space between the drillpipe and the $9\frac{5}{8}$-in. casing caused a low liquid velocity point and poor wellbore cleaning of the drilled cuttings.

KEY LESSONS

Where adequate hole-cleaning is not possible, the penetration rates must be controlled to ensure effective removal of all cuttings from the well. A 7-in. tieback string should be used for future wells with similar reservoir pressures in the Sabah field in order to enhance hole-cleaning capacity and to minimize associated problems observed on G-55. The equipment necessary should be assembled in advance.

Hydrocarbon-based fluids are particularly susceptible to increases in density due to natural solids accumulation. This warranted accurate monitoring of the Sabah crude oil to ensure that cuttings from the re-injected oil would not exceed 1%. It is important to minimize the amount of drilling fines re-circulated back into the wellbore. High fines concentrations will increase the fluid density and cause slugging, as well as increasing the likelihood of spikes in bottomhole circulating pressure (BHCP).

During conventional drilling operations, the mud weight often increases as a result of the milling action of the drill bit on the formation and the subsequent increase in the likelihood of cutting fines being re-circulated in the fluid system. It became apparent that the surface system was unable to adequately remove all of the solids with a particle diameter of less than 10 microns. By reconfiguring the solids handling system, this could be prevented on future wells.

For the 1,353 ft drilled, the density of the Sabah crude increased from 6.78 lbs/gallon to 6.85 lbs/gallon. The bottomhole pressure would have therefore been equally affected. However, the losses to the formation meant that new oil was sufficiently close to the original weight.

It is crucial to minimize the time with the pumps off during a connection. The rig crew should be on the floor with the tongs ready to break off the kelly as soon as it is bled off. Every effort must be made to start the pumps as soon as possible after a connection has been made.

Killing the well to change the RCD elements meant that the goal of continuous underbalanced pressures was compromised. The EM-MWD (E-Pulse) electromagnetic tool proved to be reliable in the Sabah field in monitoring wellbore trajectory and transmitting valuable data.

Clear communication during operations and ensuring that the UB drilling well program is carefully followed is important for successful operations.

A complete data acquisition system that can communicate and capture data from all sources is absolutely necessary for reservoir characterization, and ample time should be allotted to put such a system in place as well as to test that it functions correctly.

The effect of long connection periods could be greatly reduced by proper operating practices.

CONCLUSIONS

The Zueitina Sabah G-55 well was successfully drilled to within 200 ft of the target total depth with a usable 1,353-ft drain in the Beda "C" Reservoir. Productivity on Sabah G-55 was significantly multiplied compared with offset wells in this field, notably the G-53 and G-46.

The success of underbalanced drilling operations on the Zueitina Sabah G-55 horizontal well were hampered by recurring slugging and the subsequent pressure spikes that could have caused significant formation impairment. It was not possible to capture complete reservoir-characterization data due to inconsistencies between the instrumentation of the rig and the underbalanced equipment. This problem was overcome in a second well.

Planned and applied correctly, underbalanced drilling technology can address formation damage, lost circulation and poor penetration rates. The ability to investigate and characterize the reservoir while drilling is another important benefit of underbalanced drilling.

This article was adapted from a presentation made by Hani Qutob, Chief Reservoir Engineer-UBD Systems, Weatherford International Inc, at the 2006 IADC European Well Control Conference & Exhibition, held 4-5 April in Amsterdam, Netherlands.