STIMULATION OF WATERED-OUT INACTIVE/MARGINAL WELLS WITH DUAL COMPLETIONS

BOTTOM LINE

Over 340,000 wells are inactive (shut-in) in the United States, of which 34,000 are in Louisiana. These wells were generally temporarily abandoned because they were no longer economical to produce, often because of high water cut. Many of these wells, particularly in the Gulf Coast, suffered premature high water production rates due to coning, channeling, or both and left 40 to 90 percent of the oil in place behind. For those wells, the technology now exists to recover those reserves, the Downhole Water Sink, utilizing a dual completion to create a sink in the aquifer while producing from the oil zone above.

PROBLEM ADDRESSED

The Downhole Water Sink (DWS) has been demonstrated to be an effective stimulation approach for certain high watercut wells that have prematurely watered out. The problem addressed is to understand the reservoir mechanisms, identify candidate wells, simulate the results, and design an optimum completion.

KEY WORDS:

Aquifer
Channeling
Coning
Downhole Water Sink
Dual Completion
Reservoir Simulation
Water Cut

TECHNOLOGY OVERVIEW

Watered-Out Well Stimulation Concept and Project for louisiana Reservoirs

Many of the temporarily abandoned (shut-in) wells have become uneconomic due to the high cost of producing and disposing of the water. Many of these wells became uneconomic prematurely, leaving valuable oil in place. The problem to be addressed is to identify those wells and derive a method for assigning economic value to them. The cost of water can be considerable. Shell Oil estimates the world average at \$0.67/bbl. U.S. costs range from \$0.17 to \$2.50/bbl. The components of this cost include lifting, pumping, separation, de-oiling, filtering, and injecting. With known costs, those related to the volume of water and those relatively fixed, and known revenues, the water-cut at the economic limit can be calculated as well as the profit margin for an assumed cost and price of oil for the purpose of deciding to produce, shut-in, or plug. Given the age of the average on-shore well and the substantial fraction of the domestic production coming from marginal wells, it is critical that the productivity and valuation of marginal wells be assessed using technological advances in downhole water control.

LSU has had a long-standing joint industry research effort to quantify and optimize the technology of downhole water sinks (DWS) to enhance the value of inactive wells with bypassed reserves. This includes modification of DWS technology for removal of water damage, building a system for candidate screening, developing a technical performance model and software for computing the incremental recovery and the dollar value associated with those barrels. DWS is a well completion and production technique for bottomhole water control in reservoirs with bottom/edge water coning, cresting and under-running. It controls water by diverting the water inflow pathway to the well using dual completion and hydrodynamic mechanism of forced bottomhole water drainage.

LSU has constructed a pie-shaped sand pack physical model of a well with bottom water drainage that visually demonstrates the displacement of the water with forced downhole water drainage. It never gets back to the pre-breakthrough oil saturation, however, due to the hysteresis of the oil/water relative permeability.

Dual Well Completions with Downhole Water Drainage—DWS Technology

The DWS technology requires a dual completion with the upper perforations in the upper section of the oil zone, the lower perforations in the water zone below the original oil-water contact. Oil is produced up the annulus. Water is produced up the tubing, creating a reverse coning effect. Reservoir energy is from the aquifer water drive. A variation would have a third set of perforations in a lower water zone not in communication with the producing formation. The water from the producing formation would be pumped by a

Based on a workshop sponsored by PTTC's Central Gulf Region in Shreveport, Louisiana on May 23, 2006.

SPEAKERS:

Marginal Well Upgrade Concept and Project for Louisiana Reservoirs; and Dual Well Completion with Downhole Water Drainage,
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Assessment of Added Value to Wells in Louisiana - A Case Study; and Identifying Reservoir/Well Candidates - A Method and Software;
William C. Kimball, Kimball and Associates

Understanding the Mechanism of Bypassed Oil in Water-Drive Reservoirs,
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SONRIS - Source Data on Reservoir/Well Candidates in Louisiana,
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downhole pump to the lower zone, rather than to the surface.

Several early field tests of DWS (with no rigorous design) were published in the mid 90s in Canada, East Texas, and Indonesia. In the Indonesia example, oil production improved from 241 bbl/day and a water cut of 84% to 298 bbl/day and a water cut of 18% in the oil stream, by draining 2,610 bbl/day of water. In a designed application in Bakersfield, California, a computer model was used to predict the oil recovery at various water withdrawal rates. The 10 year old well was originally producing 6 bbl/day of oil at a water cut of 99%. Using a designed DWS, water was withdrawn at 900 bb/day and the oil stream improved to 25 bbl/day at a 58% water cut. Similar results were achieved in Louisiana and Venezuela.

Assessment of Added Value to Wells In Louisiana—A Case Study

There are numerous shut-in wells in Louisiana, many of them deemed not profitable due to high water cut. Implementing newer technology has the potential to make a number of these profitable again and recover bypassed oil. This was the case with the West Delta Block 84 field in Plaquemines Parish. The field was discovered in 1955 at a depth of 14,500 feet. Ultimately the field produced 9.8 million barrels of oil and 21 BCF of gas from 25 producing wells. While there were several producing horizons, half of the production was from the KEKF-R1 reservoir. The field was shut-in in 1990 and remained so through 2000. A study and simulation was then done to evaluate the reserves and economics that could be achieved with modern technology. The original plan was that the KE-1 and KF-1 formed a single communicating reservoir, the KEKF-R1, but the waterflood of the KF-1 was ineffective in the KE-1 and reserves were bypassed.

A thorough reservoir study and characterization was conducted with engineering, geological and geophysical data to quantify the original oil in place and where and how much was remaining. The BOAST reservoir simulator was then used to run a number of scenarios, including the remaining primary reserves from the one producing well, secondary reserves recoverable through a new waterflood design with existing wells, and enhanced reserves through a downhole water sink. The optimum recovery was predicted by re-completing two producing wells in their upper perforations, reinstating the flood in the KF-1 zone and instituting a flood in the KE sand. The model predicted a future recovery of 1.7 million barrels under this design. The last run compared the single well primary recovery with and without DWS. Without DWS, the forecast oil was 27,700 barrels while with DWS, recovery increased to 82,000 barrels.

Understanding the Mechanism of By-passed Oil in Water-Drive Reservoirs

Early breakthrough of water, resulting in bypassed oil, occurs in bottom-water systems and edge-water systems. This study examines the reasons for oil bypass in edge-water systems and possible solutions. Frequently the problem is the result of heterogeneities and the resulting viscous fingering. It can also be caused by stratification and high horizontal permeability relative to vertical. Even in relatively homogeneous reservoirs, water can under-run the oil and cause coning. A reservoir model was built to study the effect. It became clear that in situations of unstable flow from high production rates, there is a much higher likelihood of early breakthrough and bypassed oil. Then possible solutions were simulated, including a well penetrating the oil and water section and a dual completion DWS. The study concluded that oil can be bypassed even in homogeneous reservoirs, that water under-running and coning could cause as much as 62% of the oil to be bypassed. Further, that oil bypassing is mainly stimulated by high end point mobility ratios, low dip angles, and large well spacing and that the best completion strategy in edge-water systems is the use of deep-penetrating or dual-completed wells.

SONRIS—Source Data on Reservoir/Well Candidates in Louisiana (Strategic Online Natural Resources Information System)

The Louisiana Department of Natural Resources has developed a very robust and user friendly oil and gas well database and mapping system (very similar to that developed by the Kansas Geological Survey). There are versions for users with fast and slow internet connections that are publicly available at no charge through their website www.dnr.state la.us. The website provides access to the electronic database, document images, and interactive GIS maps. The type of information available includes well data and histories, well engineering and tests, production, injection, operator information and lease records. It allows the user to screen and sort the database by a number of criteria from operator to field. Documents available include unitization orders, well files, well logs and production reports. Data can be downloaded in spreadsheet format. In the GIS mode, the selected wells can be spotted along with geological features and political boundaries and the usual GIS features and downloaded to the user.

Identifying Reservoir/Well Candidates—A Method and Software

The objective of this methodology and software is to identify, screen and prioritize worthwhile and economic marginal wells, even with incomplete or missing information. This screening and "expert" system follows others that have been used to screen for CO_2-miscible displacement and selecting an EOR method. It is designed to be a knowledge-based system "getting its power from the expert knowledge that has been coded into facts, rules, heuristics and procedures." The screening program is modeled after the PROSPECTOR program, an expert system used to identify ore deposits and is designed to reduce the risk of overlooking unfamiliar possibilities. The basic procedure is

- Using SONRIS (or any other similar database for other states), extract the relevant data, however slim it might be
- Manipulate and make decisions and conclusions based on the available information in order to screen most likely to succeed candidates for more detailed studies
- Perform risk and uncertainty analysis to deal with insufficient and uncertain data and give the user a feel

for the value of the information used to reach the prioritization

Data input includes production, well tests and pressures, perforation depths, core data, log data, seismic and geological models. Possible uncertain analysis includes original oil in place, drive type, water problem, the cost of restoring production, oil prices and ultimate recovery. Tools of analysis include traditional discounted cash flow and risk assessment with Monte Carlo simulation, decision tree, and options valuation using the Black-Scholes method.

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The not-for-profit Petroleum Technology Transfer Council is funded primarily by the US Department of Energy's Office of Fossil Energy, with additional funding from universities, state geological surveys, several state governments, and industry donations.

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