CASE STUDY

High-Energy Elastic-Wave-Based EOR Crosses Flow Barriers in a Canyon Sand To Reverse Oil Decline

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Over the past several decades, engineers and researchers have continually explored ways to release valuable and significant quantities of oil left behind by primary and secondary production methods. Many flow-based enhanced oil recovery (EOR) methods have long been proven to work well in connected formations, where a fluid can communicate between injection and production wells.

But in fields characterized by isolated, noncontiguous reservoirs, flow-based EOR methods cannot work. Conventional stimulation methods such as acidization, because they treat only one well at a time, are inefficient, time consuming, and uneconomic for fieldwide production enhancement.

The use of high-energy elastic-wave-based EOR overcomes these communication issues.

The surface of a canyon sand area clearly shows the spatial separation of each flow/hydrocarbon reservoir unit.

Elastic waves propagate powerfully through rock and fluids to effectively enhance oil recovery in formations located both vertically and horizontally within about a 1.5-mile radius of the source well. The following case study demonstrates the issue, the process, and the result of a typical course of action.

The Issue

With rapidly declining production in a southwest Texas' canyon sand, a producer was facing the reality that its field would play out in about 2 years, at which point it would have to be shut in. Over the field's 70-plus years of production, its historic decline rate was about 46% and the average well was eking out just 3 B/D.

The producer understood that water or CO_2 floods were out of the question due to the isolation of each well's sand lens. Having heard about elastic-wave EOR's ability to traverse those barriers, the company asked Zencor Tools to field-test its procedure. This would determine whether the field could return to productivity or would have to undergo a hugely expensive shut-in process.

At that point, Zencor had yet to test its results in these types of vertically and horizontally isolated reservoir systems and were greatly interested in performing a case study **(Fig. 1).**

Test Preparation

The installation of an elastic-wave EOR tool starts by selecting an abandoned well that is centrally located to the most-dense production area. An elastic-wave EOR tool is placed to provide the greatest enhancement to oil recovery and extension of field lifespan. For the canyon sand test, the selected well brought about effective EOR in the 70 wells that were part of the treatment process **(Fig. 2).**

Tool Installation

Before installing the tool, the abandoned well must be cleaned out and a short, 50-ft cement plug placed above the perforations. The cement plug

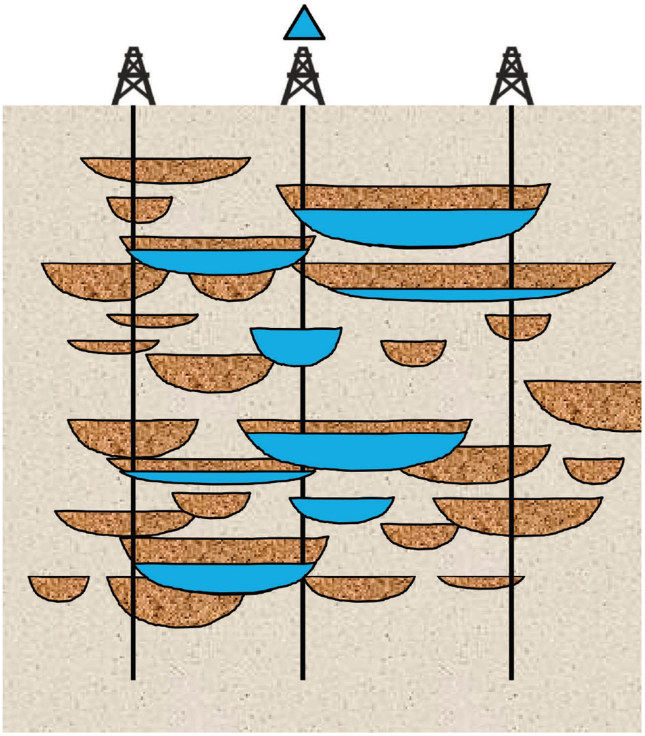

Fig. 1—Cutaway drawing of a canyon sand reservoir system showing vertically and horizontally separated reservoirs.

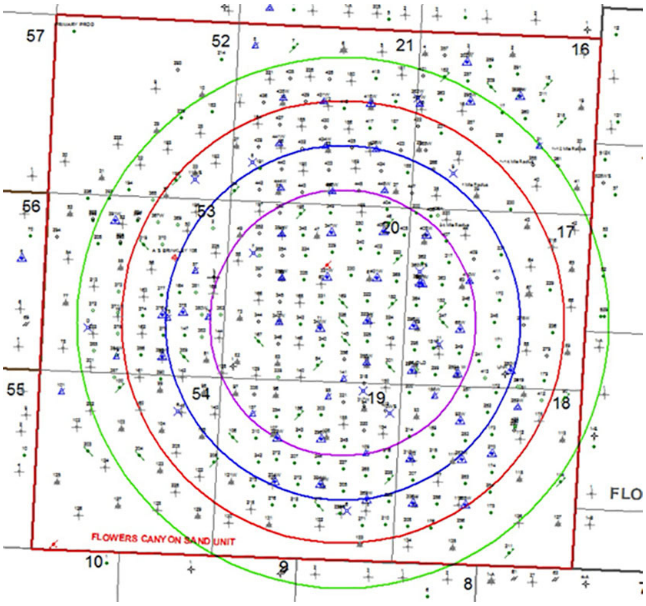

Fig. 2—Map of the test field area showing concentric circles: 0.75-, 1.0-, 1.25-, and 1.5-mile radii around the source well.

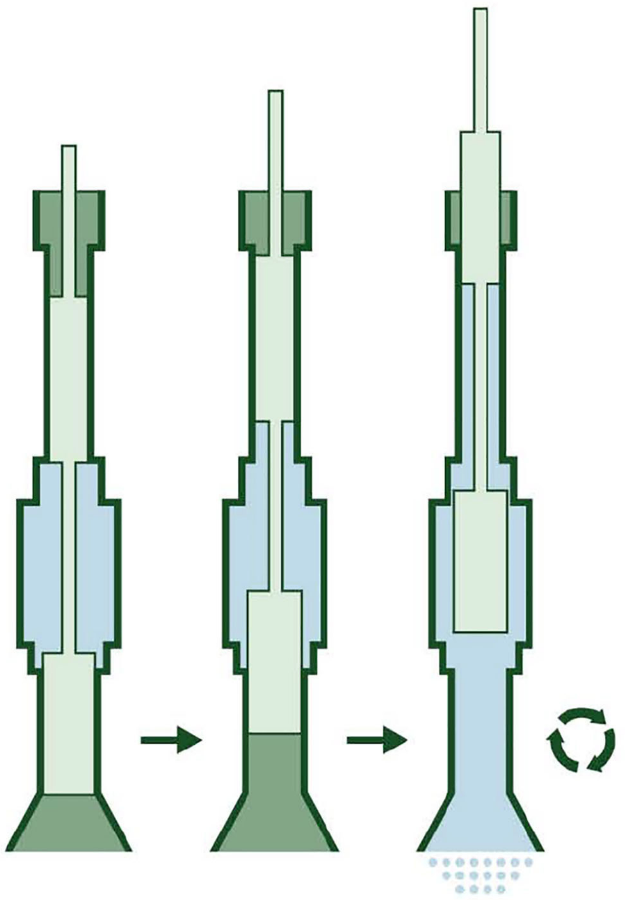

Fig. 3—Tool cross section showing plunger cycle as pumping unit moves from bottom-of-stroke to top-of-stroke and plunger exit with instantaneous release of compressed water.

prevents formation gas from entering the wellbore and interfering with the tool's performance.

The tool is then run into the well on tubing; sucker rods then follow with the polish rod spaced and connected to a surface pumping unit. The pumping unit is then started to begin EOR.

No maintenance is required other than lubrication of the stuffing box. For this test, the depth was set at 3,500 ft, and while there is no physical limit on depth other than rod string length, it can generally be effective down to 8,000 ft.

How It Works: Making Waves

Inside the tool are two plungers of dissimilar size. The larger, lower plunger contains a traveling valve; the smaller, upper plunger is blocked off. The smaller plunger remains in the barrel throughout the cycle, acting as a seal for the system **(Fig. 3).**

In action, the lower plunger lifts more water into the tool's compression chamber than the upper plunger can evacuate, building up pressure of approximately 3,500 psig between the plungers. When the lower plunger exits the barrel, the action within milliseconds releases high-energy hydrodynamic elastic waves every 10 seconds and generates 2 MW of power on each stroke. Repeating this cycle six times per minute creates a continuous flow of high-energy waves that penetrate all zones in reach of the waves. The high-energy elastic waves exiting the tool travel at 1.5 miles/sec, pass through the plug, and exit perforations, with no degradation.

The tool's operation is tracked through dynamometer cards. Measuring the load on the pumping unit created by the compression of fluids in the tool verifies that it is operating correctly.

Mechanics: How High-Energy Elastic Waves Mobilize the Trapped Oil

Propagating through the reservoir, these elastic waves overcome the capillary barrier pressure—the meniscus—between the oil and the rock. This results in favorable "shaking" of the trapped oil, releasing it to flow into the producing wells that are within the 1.5-mile effective radius of the tool.

This method requires the presence of two governing criteria, according to Pride et. al. "The main message of this study is supported strongly by numerical simulations: Seismic stimulation will mobilize trapped oil, thus increasing oil production, when two dimensionless criteria are met."

While the term "seismic" is used by Pride et. al., it is equivalent to Zencor's description of "elastic wave."

Pride et al. add, "The first condition is the static-force requirement that when a seismic wave pushes on a trapped oil bubble, the radius of curvature of the downstream meniscus of

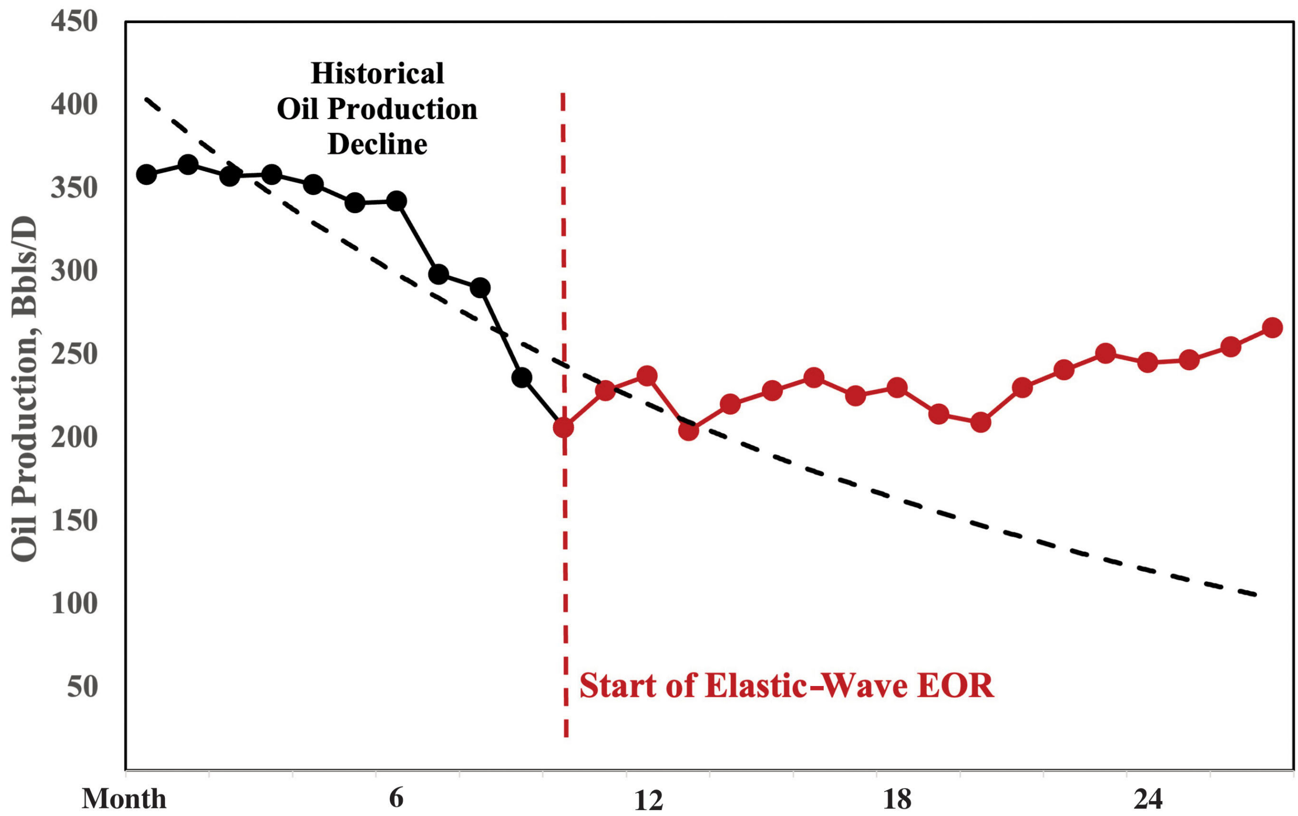

Fig. 4—Elastic-wave treatment.

the bubble is reduced sufficiently to get through the pore-throat constriction that is blocking its downstream progress. The second condition is the dynamic requirement that in a cycle of the time-harmonic stimulation, the meniscus has enough time to advance through the constriction before the seismic force changes direction and begins to push the meniscus upstream."

Who Knew?

While proper application of high-energy elastic waves is relatively new, oilfield workers as long ago as the 1950s had observed that after a natural earthquake their wells produced more oil, sometimes as far as 200 miles from the epicenter. Recent years have seen the perfecting of tools designed to create these waves to maximum production efficiency, such as the one used in this study.

These Waves Are All Good

With anthropogenic seismic activity increasing in many oil-producing basins, the question arises as to whether this treatment is confined to positive results. Research has shown that these waves are not connected to any surface damage and are completely safe to use. According to Irfan et al., "On the basis of critical interpretation of reported work, elastic-wave stimulation appears capable of increasing efficiency of oil production in depleted reservoirs without damaging seismicity effects such as micro-earthquakes."

Results

Production was monitored on a per-well basis each month for 17 consecutive months. Statistically significant production increase began after approximately 4 months of treatment. Instead of a decline rate of 46%, the field converted to an incline rate of 8%. Production for the field rose by 155 B/D, an increase of 175% over the historical decline curve. Overall, the elastic-wave treatment recovered an additional 44,000 bbl of trapped oil during the 17-month case study **(Fig. 4).**

Cost-Effectiveness

Zencor Tools leases the tool to operators at a moderate cost per month, with no other costs incurred other than normal pumping unit expenses.

This emissions-free procedure has been certified as a Tertiary EOR Process under the **Texas Railroad Certification under the Railroad Commission of Texas (RRC) Statewide Rule 50** allows any producer employing this unique and patented method to reduce severance taxes on total oil production by 50% for a 10-year period after proving to the RRC that the producer has used it with positive results observed, underpinned by one full year of operational data. These savings can reach millions of dollars over the 10-year period for most producers.

Conclusion

This treatment successfully revived what had been a spent field, extending its expected productive life by more than a decade. Its low-cost and simple installation, combined with its certification under RRC's Rule 50 severance tax reductions, makes it especially attractive in Texas. **JPT**

FOR FURTHER READING

Seismic Stimulation for Enhanced Oil Recovery *by S.R. Pride, Lawrence Berkeley National Laboratory; E.G. Flekkoy and O. Aursjo, University of Oslo.* Geophysics, Society of Exploration Geophysicists.

Seismic Stimulation and Induced Seismicity in Oil Reservoirs: A Review of Applications to Enhanced Oil Recovery (EOR) *by Md. Irfan, C.P. Lenn, and D. Ghosh, Universiti Teknologi Petronas.*

AUTHOR

Bill Wooden is the CEO of Zencor Tools LLP. One of the original founders of the technology, he has overseen more than 200 tool deployments in North America, Middle East, Asia, and North Africa. He holds BSc degrees in math, chemistry, and petroleum engineering from The University of Oklahoma.