Value of In-Situ Seismic Waves—Regain Lost Reserves, Increase Oil Cut

When Occidental of Elk Hills (Oxy) opted to explore a new enhanced-oil-recovery (EOR) method—in-situ seismic stimulation—to increase oil recovery in declining reservoirs, liberating residual oil was but one outcome. Oxy's seismic-stimulation project offered improved oil recovery and increased flow, positive impact on relative phase permeability, and an understanding of the magnitude and extent of the stimulated area. This technology and project results are based on and can be correlated to oil response resulting from natural earthquakes. It is the first departure from variants on conventional stimulation methods (thermal, polymer, chemical, microbial) to be introduced commercially since the 1970s. While efforts were made in the 1980s to duplicate earthquake effects by use of vibrators above a targeted zone, these attempts had disadvantages that limited commercial viability.

Hydro-Impact stimulation services developed by Applied Seismic Research Corp., currently in use in the U.S. in California and Texas, involve the placement of tools to generate subsurface shockwaves that mimic primary waves generated by earthquakes. These shockwaves, generated every 10 seconds, produce power ranging from ≈1 to 10 million watts with pressure at the wave front that can be in excess of 4,000 psi. The waves, traveling at approximately 1½ miles/sec, generally are noticeably felt on the surface only in close proximity to the wellbore, but they have a significant measured seismic signal at distances of ¾ mile from the source **(Fig. 1).** Historically, effects from sonic stimulation could reach only 20 ft. The waves affect oil-bearing strata and increase the potential for oil flow by inducing coalescence of residual oil. The effect of the seismic shock: oil droplets are dislodged from the pore wall and coalesce into larger droplets that become mobile and move into flow streams that then begin to move into any existing flow system such as fractures.

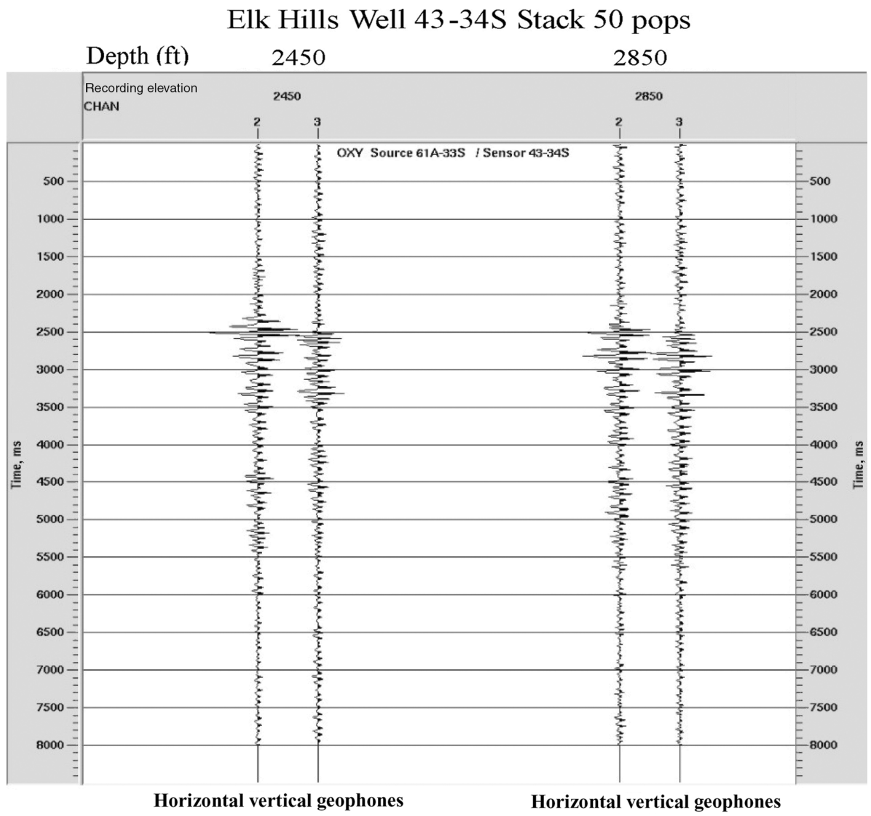

Fig. 1—Field results from a study conducted at the Lawrence Berkeley Natl. Laboratory show a strong signal at ¾ mile from the source, proving that in-situ seismic-stimulation shockwaves can be delivered to this distance and can possibly affect production on wells located within this distance. Recordings were made at two different levels to rule out any possibility of an anomaly.

In some cases, reservoirs exhibit a permanent increase in oil cut as a result of a permanent fieldwide improvement in injectivity when deployed on injectors, but this is unpredictable. Other fields return to the original decline soon after seismic stimulation is stopped and require stimulation on a continuous basis.

Because the seismic wave passes through the wellbore casing and cement within microseconds, it does not damage the wellbore or formation. The wave, propagating in all directions to eventually become an elastic wave, also can be used simultaneously with ongoing injection processes and considerably increases injectivity both in the injection well in which the tool is installed and other injection wells within the affected area.

Benefits Beyond Mature Fields

The technique can be deployed in nearly any well configuration and used in depleted, abandoned, or currently producing fields. Successful results have already been achieved in sandstone, carbonate, and diatomite formations when the method is used in conjunction with waterflood or natural waterdrive. Typically, stimulation technologies such as hydraulic fracturing address a single well, and other EOR processes target single horizons. With in-situ seismic stimulation, boundaries are eliminated, and equal stimulation effects can be witnessed in multiple horizons.

Spurring Production

In the Elk Hills field, located near Bakersfield, California, Oxy initiated a seismic stimulation pilot in October 2003 and has expanded the pilot as part of its enhanced recovery operations. Using two idle wells, in-situ seismic tools were installed in a sealed wellbore above a cement cap. A basic tool uses two plungers to compress fluid that is drawn into a barrel and then releases the fluid during the upstroke, creating a seismic shockwave.

Before the project began, oil production from 73 pilot wells within a ½-mile radius around the well in which the tool was installed was 1,556 B/D in December 2003. After the onset of seismic activity as shown in **Fig. 2,** oil production increased by 42% to 2,212 B/D (by 60% if based on the projected trendline) and continues to increase over time. During this same timeframe, oil cut increased from an average of 16.8 to 21.6%, or an overall increase in oil cut of 28% (by 47% if based on the projected trendline).

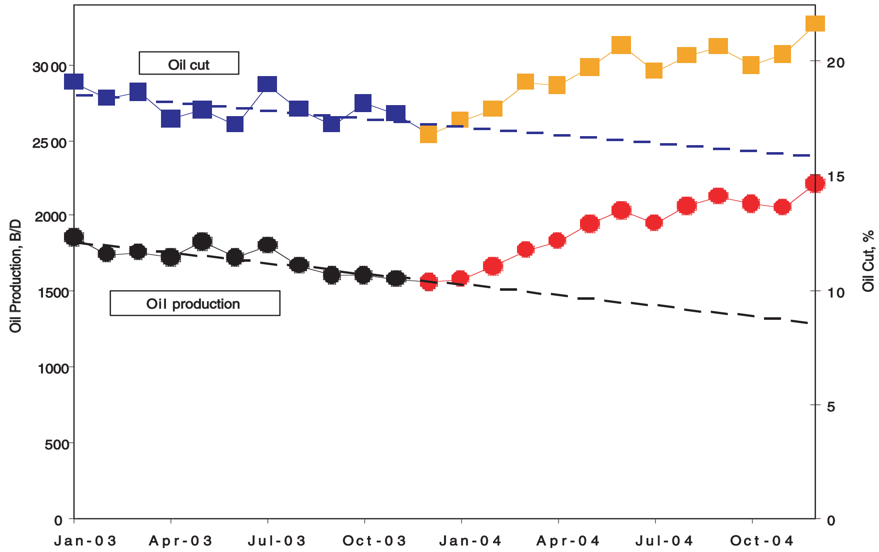

Fig. 2—In the Elk Hills field, data from 73 wells within a ½-mile radius of the seismic-stimulation tools showed an increase in oil production of 60% (850 BOPD). Oil cut increased by 47%.

Oxy has begun use of the new technology in the Wasson 72 field, located on the northwest shelf of the Permian Basin, and expects to produce an additional 124,000 bbl of oil over the next 2 years as a result of using two in-situ seismic-stimulation tools. This very mature asset was discovered in 1940 and produced under primary recovery with solution-gas energy until 1980, when water injection began. Since that time, there has also been CO_2 injection and multiple phases of infill drilling. Of the 333 million bbl of oil in place, only 75 million bbl (23%) has been recovered. Oxy's estimate of increased production is based on a conservative 5% increase in oil cut/oil production, while computer modeling of this field projects increases to exceed 15 to 20%.

Considered inexpensive and eligible for enhanced-recovery tax credits in Texas, the in-situ seismic procedure is patented worldwide. JPT