

PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

DE-FC26-00BC15307

PARTNERS

**ElectroMagnetic
Instruments, Inc.**
Richmond, CA

**Lawrence Livermore
National Laboratory**
Livermore, CA

Geo-BILT
Richmond, CA

ChevronTexaco Corp.
San Francisco, CA

Schlumberger Ltd.
Houston, TX

MAIN SITES

EMI Test Site
Richmond, CA

Lost Hills field
Kern County, CA

Kern River field
Kern County, CA

Vacuum field
Lea County, NM



*Crosswell receiver being prepared
to lower in wellbore.*

OIL RESERVOIR CHARACTERIZATION AND CO₂ INJECTION MONITORING IN THE PERMIAN BASIN WITH CROSSWELL ELECTROMAGNETIC IMAGING

Background/Problem

Crosswell electromagnetic imaging technology, based on earlier radar imaging technology, will help interpret the reservoir rock and fluid flow through the reservoir between wells. The necessary resolution to accurately map fluid properties has been missing from conventional seismic analysis.

Crosswell EM imaging is designed to give accurate measurement of oil saturations in the areas between wells. Previous logging techniques could only generate oil saturation data close to the wellbore. Crosswell EM logging can provide the operator with an actual image of fluid migration and show where specific areas of undeveloped reservoir remain.

Project Description

The Crosswell Electromagnetic Imaging Tool was developed at Lawrence Livermore National Laboratory (LLNL) from 1991 to 2000. ElectroMagnetic Instruments, Inc. (EMI) was created by former LLNL scientists to further the research and commercialization of the Crosswell Electromagnetic Imaging down-hole logging tool. EMI developed a five-well pattern test site in Richmond, CA, to continue testing and construction of the tool prior to commercial field tests.

Crosswell electromagnetic logging involves the use of a string of receivers in one well and a transmitter lowered into a neighboring wellbore and moved up and down. The development of sensitive receivers, advanced transmitters, and fiber optics was an essential part of the implementation of crosswell logging, and these advances have been incorporated into the development of the EM extended-logging tool. The DOE project has refined transmitter and geophone receiver design and deployed the EM tool in uncased, fiberglass-cased, and steel-cased wellbores.

EM logging depends on interpretation of three-components: compressional, vertical shear, and horizontal shear waves between transmitter and receiver. Using a multiple array of receivers and moving the transmitter up and down the neighboring well allows imaging of a roughly elliptical region between the wells. Several transmitter-receiver combinations are used per survey to gather data. Currently, EM logging of a 1,000 ft section of an uncased wellbore can be accomplished in 12 hours. The logging tool can be used in uncased and fiberglass-cased wells with no difficulty, and has been successfully demonstrated when one well of a pair is steel-cased. Steel casing significantly slows transmission time and interferes with the signals.

Improved crosswell logging applicable to CO₂ flooding

Accomplishments

CONTACT POINTS

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TOTAL ESTIMATED COST

\$5.1 million

COST SHARING

DOE	\$0.8 million
Non- DOE	\$0.4 million

PROJECT START/END

Start	September 11, 2000
End	August 2, 2004

WEBSITES

www.netl.doe.gov
www.emiinc.com

The first field applications of crosswell EM logging were conducted in 1997-98. A crosswell survey was conducted at Kern River oil field in California in 1998 to map the residual oil saturation and determine which factors controlled steam and oil flow in the heavy oil reservoir. Identification of the steam path allowed redesign of the steamflood to produce unswept areas. Crosswell imaging applied at Lost Hills field in California in 1997-98 imaged the waterflood performance of the Belridge Diatomite. Chevron USA Inc. used two fiberglass-cased wells to observe the results of water injection in this fractured reservoir. Imaging resistivity changes over time demonstrated that crosswell data could be used to map migration of the waterflood front, providing an excellent means for understanding reservoir dynamics and optimizing the oil recovery process of the waterflood.

The Geo-BILT tool, a modified prototype EM imaging tool designed and tested by EMI, successfully demonstrated that multicomponent logging was applicable in several different geological environments. Geo-BILT has the advantage that it is capable of single-well extended logging. The tool uses a transmitter situated 3 meters above the receivers on a line and provides a 3-D image of the wellbore area up to a radius of 50 to 250 meters. Single-well logging will significantly reduce logging cost while providing critical reservoir data.

Crosswell electromagnetic imaging was used to monitor CO₂ injection performance in New Mexico's Vacuum field, operated by ChevronTexaco. This 3-year DOE project involved development of crosswell EM dual-steel casing logging tools, software development, data processing, and imaging of low-induction frequencies. The results were used to develop resistivity models showing the distribution, size, and depth of the low-resistivity zones, which could be correlated to interwell CO₂ migration.

Benefits/Impacts

Crosswell EM imaging has been demonstrated successfully for use in monitoring steamfloods, waterfloods, and CO₂ floods. Crosswell EM imaging was proved to be 10 times more effective than the previous logging techniques used at Vacuum field to monitor CO₂ flooding. Information obtained from EM surveys will allow field operators to optimize production and produce more oil in a cost-effective manner. The progress of imaging through fiberglass and steel casing will increase significantly the application of the technique in regions where uncased wells cannot be used. The newest advances in single-wellbore imaging holds great potential for use in offshore drilling, where the expense of idling wells for logging procedures will be reduced by cutting the number of wells necessary to complete the EM survey.

Following successful demonstrations of the tool's effectiveness, specifically single-borehole imaging, imaging through steel casing, and CO₂ monitoring, EMI was purchased by Schlumberger Ltd., a major oilfield service company. Schlumberger is backing the continued development and implementation of the Crosswell EM tool with a capital investment of \$15 million, indicating their confidence that crosswell EM logging tools have a secure place in the future of the petroleum industry.