PROJECT
facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Petroleum Exploration and Production

06/2005

Calibration and Testing of Sonic Stimulation Technologies

Partners

Michigan Technological University

Sonic Production System

Wave Energy Research

Baker Atlas Wireline Services

Iowa State University

Main Site

Michigan Technological University Test Site

Manistee County, MI

Background/Problem

America has thousands of declining oil fields containing billions of barrels of oil left behind after application of primary or secondary recovery methods. Much of this bypassed oil could be recovered via enhanced oil recovery (EOR). But high capital and operating costs for EOR methods can be big hurdles for the marginal properties that typify EOR candidates. DOE's long-standing funding of EOR research has included innovative approaches that focus on low-cost, environmentally friendly technologies, such as sonic stimulation.

Sonic stimulation is an emerging technology that has been used in the last decade to enhance oil field production in a number of countries; however, these efforts have not contained sufficient scientific rigor to form a solid theoretical basis for the technology. Stimulation experts have concluded that this lack of basic understanding has led to a wide variety of tools with inconsistent yet promising results.

Scientific theories for the mechanism of sonic stimulation currently depend strongly on the levels of vibrational energy partitioned among the fluid and solid phases in the formation, yet these levels are presently unknown. Laboratory simulations are limited in their ability to provide meaningful results without knowing what levels can be achieved in the field. Theoreticians are developing models that require knowledge of absolute levels of vibrational motion, yet those levels have not been scientifically calculated. This project is intended to provide the bridge between laboratory experiments and field performance.

Project Description/Accomplishments

The goals of this field demonstration project were to design a set of sonic stimulation standards, to conduct field experiments to determine the far-field characteristics of the various sonic sources used today, and to provide fundamental observations to advance theoretical understanding of the sonication process.

In conjunction with Baker Atlas Inc., Michigan Technological University devised a system capable of recording earth motion and pressure data from downhole and surface seismic sources. The essential elements of the system are 1) a borehole test site that will remain constant and is available to test sonic sources, 2) a downhole sonde that itself will remain constant and, because of its downhole digitization capability, does not require wireline or surface recording components to remain constant, and 3) a set of procedures that ensures that the amplitude and frequency parameters of a wide range of sources can be compared with confidence.

Four seismic sources—three downhole and one at the surface—were deployed at

CONTACTS

Jerry Casteel
Director
Petroleum Technology
SCNGO
918-699-2042
jerry.casteel@netl.doe.gov

James Barnes
Project Manager
SCNGO
918-699-2076
jim.barnes@netl.doe.gov

Wayne Pennington
Project Investigator
Michigan Technological Univ.
906-487-2531
wayne@mtu.edu

PROJECT DATA

DE-FC26-01BC15165
Oct. 1, 2001-Dec. 31, 2004

Total Project Value
$1,250,509

DOE/Non-DOE Share
$999,995/$250,514

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

Michigan Tech's Reservoir Characterization Test Site during 2003-2004. The downhole sources included one piezo-electric vibrator and two oscillating water-jet tools. The surface source was a small hydraulic vibrator. They were all recorded by a downhole receiver containing calibrated three-component geophones and hydrophones. The seismic traces were analyzed in both time and frequency domains. The three downhole sources could not be seen above the ambient noise levels of the site in the time domain, but the surface source was easily observed. The surface source, the downhole piezo-electric vibrator, and one of the downhole water-jet sources could be observed in the frequency domain. The frequency band of the sources varied from a low of 18 Hz (the low end of the surface vibrator) to a high of 1,600 Hz (the high end of the piezo-electric vibrator).

A second focus of the study was to gain an understanding of the fundamental physical mechanisms of the effect of sonic stimulation on oil mobilization. A theory has been developed to account for the behavior of oil drops (ganglia) trapped in pore throats and their ultimate release through the additional incremental pressure associated with sonic stimulation. Residual oil is trapped in a pore because of the resisting capillary forces that prevent free motion of a non-wetting fluid. The application of vibrations is equivalent to the addition of an oscillatory force to the constant pressure gradient within the rock pore system. When this extra force acts along the gradient and the threshold is exceeded, instant "unplugging" occurs, and the oil ganglia may move through the pore throat.

Based on the capillary mechanisms determined for oil mobilization, the following criteria were outlined for successful seismic stimulation: 1) The shallower the reservoir, the stronger the effect; 2) waterflooded reservoirs with water saturation greater than 90% are needed; 3) the lower the oil viscosity, the better the results; and 4) optimal (resonant) frequencies should be selected (frequencies above a certain threshold may be inefficient).

Benefits/Impacts

This project provides a physically based theoretical model that can be used to improve the performance, reliability, and predictability of new or improved sonic sources. The permanent test well and the downhole sonde will comprise a test site so that other sonic sources can be developed and tested. Researchers also delineated criteria for the reservoirs most likely to benefit from sonic stimulation. This research advances the scientific foundation for an innovative technology that could provide a widely applicable, low-cost, environmentally friendly means of enhancing oil recovery in thousands of U.S. oil fields and thus boosting America's oil reserves and production.