DOE/BC/14617--T8

PROOF OF CONCEPT
OF MOVING
THRU CASING RESISTIVITY APPARATUS

DOE GRANT NO.: ~~DE-FG22-90BC14617~~

ParaMagnetic Logging, Inc.

SUMMARY ANNUAL REPORT

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DOE Project Officer: Mr. Robert E. Lemmon

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OBJECTIVES:

Our firm is dedicated to validating recently discovered technology dealing with oil well measurement instrumentation which will allow the industry to find "missed oil" and "by-passed gas" in mature oil and gas fields. This breakthrough technology will allow identification of missed oil and by-passed gas locations in wells scheduled for abandonment and will also allow increased productivity from low production wells. There is no other proven technology today that will detect such oil behind steel casing, lower the discovery risk and improve the success rate of recovery of otherwise accessible but undetected oil and gas reserves.

It is believed that there may be more missed oil around existing wells than will be found in the future by wild cat drilling in the continental United States. This new technology could substantially increase the petroleum reserves in the continental United States and obviate greatly the need to drill new wells, particularly in environmentally sensitive areas. This technology may be of particular interest initially to the independent oil companies, and will ultimately be of great economic value to the major oil companies as well. The technology will also be used to monitor enhanced oil recovery projects in the future.

This is a continuing research effort into the new field of measuring the resistivity of geological formations from within cased wells. The original research objectives are summarized as follows:

(1) Additional data confirming the feasibility of the technology is to be taken in a test well with the existing stop-and-lock apparatus which is called the Through Casing Resistivity Apparatus ("TCRA").

(2) After that data is obtained, the already existing TCRA will then be modified mechanically and new electronic components will be fabricated to test the concept of a moving apparatus called the Moving Through Casing Resistivity Apparatus ("MTCRA").

The study by ParaMagnetic Logging, Inc. of measuring resistivity through casing with the Through Casing Resistivity Apparatus is of great importance to the oil and gas industries. It is important to measure resistivity through casing for at least the following reasons: locating by-passed oil and gas; measuring water breakthrough during water flooding operations; reservoir evaluation; measurements through a drill string when the drilling bit is stopped; measurements from within horizontal wells; measurements from within existing highly deviated offshore cased wells; environmental monitoring of disposal wells, water wells, etc.; and perhaps to monitor petroleum leakage rates through storage tanks and from oil pipelines.

SUMMARY OF PROGRESS:

Objective No. 1 defined above has been completed. Additional data confirming the feasibility of the technology has been obtained with the existing stop-hold-and-lock Through Casing Resistivity Apparatus ("TCRA"). Data was obtained at the frequency of 1 Hz. The vertical spacing of each voltage measurement electrode pair was approximately 57 inches. The data proves the following: (a) the technology works as generally outlined in various patents on the subject; (b) the cement surrounding the well does not cause substantial measurement difficulties in formations having resistivities above 10 ohm-meters; and (c) the data shows that thin beds can be resolved. The data was witnessed by many industry observers from Arco, BP, and Mobil.

The entire test facility was relocated back to Woodinville, Washington from Fort Worth, Texas.

The Moving Test Jig is a laboratory instrument which realistically simulates measurements to be done later downhole. It was designed, built, and has undergone many months of testing. The Moving Test Jig has electrodes which engage the interior of a rusty piece of test casing. It is pulled through the rusty piece of test casing at various speeds of up to about 5 feet per minute. Electrical resistors on the outside of the casing allow conduction of A.C. current off the outside of the test pipe which can be directly measured. The Moving Test Jig then measures these currents independently with the technology developed under the DOE Grant. Agreement among these measurements means that we are properly measuring the parameters necessary to calculate the resistivity of formations. Agreement also means that our complex electronics work and that our theory of operation is correct.

Mr. Richard Woodhouse from BP has defined the accuracy to be achieved downhole for the Moving Through Casing Resistivity Apparatus to be the following: 3 ohm-meters plus/minus 1 ohm-meter on the low side; and 30 ohm-meters plus/minus 5 ohm-meters on the high side. We call these specifications the "Woodhouse Specifications". We hope to meet these specifications at a rate of movement of up to 5 feet per minute.

Extensive tests with the Moving Test Jig have shown that we can measure leakage currents from a piece of rusty test casing with a new method of operation. Using that new method of operation will allow measurement of 10 ma 0-peak currents at 1 Hz leaking into geological formations from the rusty casing to an accuracy of about 10 percent. This is sufficient accuracy to meet the "Woodhouse Specifications". It is anticipated now that these specifications can be achieved while the Moving Through Casing Resistivity Apparatus is drawn vertically upward within the test well at a rate of 4 feet per minute. Much electronics

has been developed to accomplish this task, including the development of 4 digit accuracy phase sensitive detectors.

PML purchased a logging truck with its own corporate funds. It has been modified to accommodate the current use. A non-magnetic Schlumberger drum has been installed. Much modification to the gear train on the truck has been finished which allows the wireline to operate within the following range of speeds: 9 feet per hour to 100 feet per minute.

A theoretical study has been completed by Dr. Clifford Schenkel and Professor Frank Morrison of the University of California at Berkeley. Their work has shown that the theory used by PML which appears in many U.S. Patents on the subject is correct. The use of a single Calibration Constant has been justified theoretically.

PML has approved and executed the contract with Arco to study the resistivity of cement. It is 100% funded by GRI. A preliminary report dated September 16, 1991 has been received from Mr. Jim Klein.

We hope to have the Moving Through Casing Resistivity Apparatus ("MTCRA") working in our Test Well in Woodinville by June of 1992. To that end, we have located and hired a world-class mechanical design engineer to design the mechanical portion of the MTCRA. The design is about 1/2 done, and fabrication has begun. New hydraulic mechanisms were discovered which solve the required mechanical problems which we call "Fauskatrons".

PML is now in the process of getting permits for drilling the Test Well in Woodinville. It will be 300 feet deep and will be logged by Schlumberger. Old rusty 7 inch O.D. casing will be installed in the test well. The Moving Through Casing Resistivity Apparatus will then be tested in this Test Well.

SIGNIFICANCE TO EOR RESEARCH PLAN:

This technology will enable the oil industry to locate and extract "missed oil" and "by-passed gas" in old oil and gas fields that was previously impossible to locate accurately. This will enable the United States to increase its oil production without drilling new holes which is environmentally desirable. This technology will also allow measurements of water breakthrough which is currently a problem limiting production in oil fields such as those found in Prudhoe Bay, Alaska.

FUTURE RESEARCH PLANS:

The MTCRA will be fabricated in Seattle and tested in our Test Well. It will then be tested in test wells provided by major oil companies.

REFERENCES/PUBLICATIONS:

Two U.S. Patents regarding the subject matter of the DOE Grant have issued which are:

1. U.S. Patent No. 5,043,669 entitled "Methods and Apparatus for Measurement of the Resistivity of Geological Formations from Within Cased Wells in Presence of Acoustic and Magnetic Energy Sources" which issued on 8/27/91.
2. U.S. Patent No. 5,043,668 entitled "Methods and Apparatus for Measurement of Electronic Properties of Geological Formations Through Borehole Casing" which issued on 8/27/91.