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Steerable Percussion Air Drilling System

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CONTRACT INFORMATION

Schedule and Milestones

FY95

Final Report

BACKGROUND INFORMATION

The advantages of air drilling over conventional mud drilling have been documented in numerous publications: improved penetration rate, reduced mud costs, negligible formation damages and immediate indication of zone productivity (ref. 1). The application of diamond enhanced inserts to percussion bits has resulted in longer drilled footage, significantly lowered cost per foot (ref. 2 and 3) and penetration rates twice as fast as extremely high weight-on-bit rotary air drilling (ref. 4).

Percussion air drilling, unfortunately can only be used when the following conditions do not exist (ref. 5):

- Known areas of large ground water flows
- High formation and pore pressure which needs to be contained by the mud hydrostatic pressure
- Presence of sour gas
- Weak formations which require mud in the hole to prevent sloughing

Directional drilling, however, is very much limited to mud as the drilling fluid. Attempts to drill directionally with air using tricone rock bits and downhole PDM motors have not been very successful. The absence of drilling mud required to lubricate the rotor/stator and bearing assemblies has caused premature failures of downhole PDM motors and resulted in expensive maintenance and drilling costs. Furthermore, the high rates of penetration provided by percussion air drilling make PDM air drilling become less attractive.

Conventional percussion air drilling tools, commonly known as downhole hammers, on the other hand, depend on the rotation of the entire drill string to provide a means to rotate and index the percussion bit. This dependence is made necessary due to the lack of a downhole air motor

to complement the percussive actions delivered by the downhole hammer. Downhole turbine or PDM motors, being designed to produce high torque and RPM required to disintegrate rocks by fatigue or abrasion methods, are not compatible with air hammers. Without a downhole means to rotate the bit, direction control of the well bore is very limited if not impossible.

Since June 1991, Smith International has been actively working on the design of an air-powered drilling tool which is coherently able to impact as well as to rotate the bit, i.e., a drilling machine which performs functions of both a downhole hammer and a downhole motor. Two prototypes of such a rotational hammer have undergone field testing since early 1992. These prototypes, designed and built around existing hardware due to limited budget, were used to prove the rotational mechanism concept by drilling a number of surface holes at 40 to 50 foot intervals in Kentucky and West Virginia.

OBJECTIVES

The cost-sharing contract between the U.S. Department of Energy and Smith International provides the funding to further develop this concept into two complete steerable percussion air drilling system prototypes, each integrated with a navigation tool (wireline steering tool), a bend sub, stabilizing devices, and to conduct laboratory and field testing necessary to prepare the system for commercial realization. Such a system would make available for the first time the ability to penetrate earthen formations by the percussion method, using compressed air as the drilling fluid, and at the same time allow the directional control and steering of the drill bit. While the drill string is not rotating (slide mode), one can orient to build angle in the desired direction at a predictable rate. This build rate can be in the range of 1-20 degrees per one hundred feet and proceeds until the

desired inclination or direction has been obtained. The drill pipe is then set in rotation, nullifying the effect of the bend angle, and causes the assembly to drill straight. The sliding procedure can be repeated as often as corrections for hole's inclination or direction are needed.

PROJECT DESCRIPTION

I. Design and Fabrication

The above referenced contract calls for the design and fabrication of the following components:

1 - Rotational Hammer: Two downhole hammers with built-in rotational mechanism:

Hammer OD: 6 3/4" to 6 7/8"
Hammer Length: 5 to 7 feet
Rotational Speed: 20 to 30 RPM
Output torque: 1,000 ft-lbs max.

2 - Percussion Bits: Up to 14 Diamond Enhanced bits required to conduct field tests, as described in the Future Work section, either 7 7/8", 8 1/2" or 8 3/4"

3- Bend Subs: Either fixed or adjustable angle bend subs, from 1/2 degree to 3 degrees

4 - Stabilizers: Near-bits and other stabilizers required in the bottom hole assemblies

5 - Running gear for wire-line steering tool: Two sets of the running gear modified to provide shock protection for the steering tool. The downhole probe is retrievable but is semi-rigidly attached to an anchor sub via elastomer shock isolators. A section of the wireline connects the probe assembly to a wet-stab connector located in the vertical section of the hole. A sinker bar assembly mating with this wet-stab connector

and having its top end connected to the wireline is the only part that needs to trip out and in of the hole when a pipe is added to the drill string.

II. Laboratory and Field Testing

Part of Smith International's contribution to the project is a laboratory flow loop equipped with a test fixture capable of testing the hammer at different inclinations and a data acquisition system with instrumentation required to measure the striking frequency, impact energy, output torque and pressure rises and falls in different chambers. The field testing program to be conducted next year is discussed in details in the Future Work section.

RESULTS

As of October 15, updates of the works performed are as follows:

1 - Design and build a test fixture equipped with a 1200 CFM air compressor capable of testing the hammer operation at open or close positions and at different weights-on-bit.

2 - The instrumentation and data acquisition system is currently capable of capturing the pressure profiles at different chambers and determining the striking frequency, impact velocity, and shock level. The torque sensor will be added in December.

3 - Complete the design of the new rotational hammer. A laboratory prototype is being manufactured and will be ready for laboratory testing in November. Findings from these tests will be used to modify the design of the field version. Two field prototypes are to be built, laboratory tested and ready for field tests in early 1994.

FUTURE WORK

The first two field tests, limited to straight hole drilling, will take place in the first quarter of next year. The objectives of these tests are to develop an understanding of the rates of penetration, mean-time and footage drilled between failures and to identify wear patterns and problem areas.

The following two field tests are scheduled in the second quarter and involve drilling directional shallow holes. The objective is to test the tool's "steerability", i.e., the ability to build or drop angle and to drill straight with the same bottom hole assembly. The effects of bend angle and stabilizer design and placement on the build rate will be studied by modifying the Bottom Hole Assembly Program (BHAP) which was developed for conventional drilling, to better represent the behavior of a hammer bottom hole assembly. Prediction of the build rate and the BHA behavior will be verified in these field tests. Single or multi shot magnetic survey tools and/or wireline steering tool will be used to confirm the hole inclination and direction.

The third and fourth quarter will involve the drilling of three horizontal wells in the U.S. continent. Different stabilizer designs such as integrated blade, either 4 or 5 or full cover spiral, or roller stabilizer will be tested. The tool's capability to reach out horizontally and the magnitude of additional air volume required to clean the horizontal hole while the drill string is not rotating will also be experimented with. The modified wireline steering tool will be used for navigational purposes.

A wireless directional MWD tool that can transmit data in air would greatly improve the system's efficiency. The development of such an MWD tool would take several years and is certainly beyond the scope of this project.

However, the study into the feasibility of transmitting microwave energy through the hollow drill string, which acts as a wave guide, or electromagnetic waves through the earth formation as telemetry means is being discussed as parts of the contract.

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