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Steerable Percussion Air Drilling System

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DISCLAIMER

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7.1 Steerable Percussion Air Drilling System

CONTRACT INFORMATION

Contract Number	DE-AC21-92MC28182
Contractor	Smith International, Inc. P.O. Box 60068 Houston, TX 77205-0068 (713) 233-5428 (713) 233-5205
Contract Project Manager	Huy D. Bui
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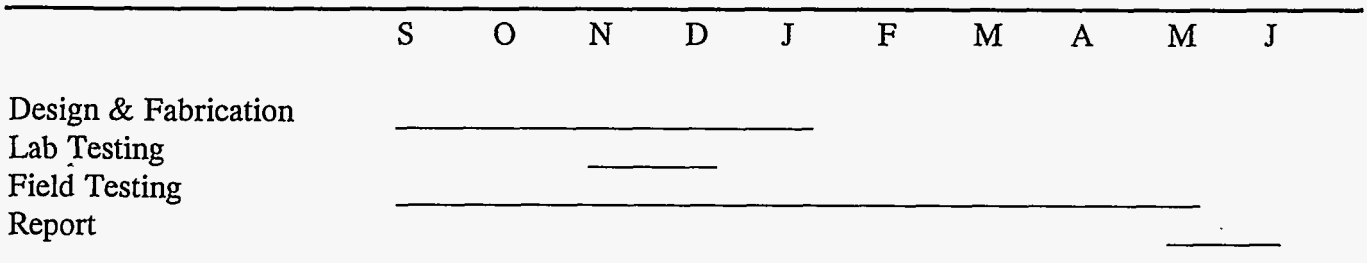
METC Project Manager	Albert B. Yost II
Period of Performance	September 30, 1992 to May 31, 1995

Schedules and Milestones

FY95 Program Schedule



BACKGROUND INFORMATION

The Steerable Percussion Air Drilling System (SPADS) is an attempt to make possible for the first time the use of air percussion method to drill directionally in hard formations. Rock disintegration is accomplished as a result of the transfer of the percussive energy from the piston-to-bit impact on to the formation, as opposed to the constant crushing force applied by the collar weight of a large magnitude in conventional drilling [1].

The heart of SPADS is a rotational mechanism, that permits and induces the bit's rotational motion independently of the drill string's rotation. In contrast, the conventional percussion drilling tools employ an external rotational system located on the ground surface to rotate the *entire* drill string. Consequently, these tools suffer from an inherent limitation of permitting straight hole drilling only. SPADS on the other hand enables the capability for directional control of the well bore, since the entire drill string is not required to rotate with the bit [2].

As compared to mud or air powered PDM motors, the advantages offered by SPADS are: directional drilling at high penetration rate, reduced mud costs, negligible formation damage and an immediate indication of hole productivity [3] [4].

OBJECTIVES AND PROJECT DESCRIPTION

The cost-sharing contract between the U.S. Department of Energy and Smith International calls for the design, fabrication, and the laboratory and field testing of two complete prototypes as follows:

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-lb max

2. Percussion Bits: Up to 14 Diamond Enhanced bits required to conduct field tests 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.

The two prototypes shall undergo lab testing to optimize impact energy prior to the field test. The field test plan calls for:

1. Straight hole testing: to harden the system's capability of drilling through hard rock independently from the drill string rotation.

2. Directional hole testing: conduct three shallow directional field tests to evaluate build rates as a function of bend angles and placement of stabilizers, effects of side loads and reactive torques, and system reliability and mean time between failures.

3. System field testing: conduct up to three high angle or horizontal field tests to prove the system capability for commercialization.

In addition, the contract also calls for the evaluation of Geoscience Electronics Corporation's (GEC) electromagnetic MWD tool as a means to telemeter directional data.

RESULTS

1. Lab Testing

An in-house testing facility for SPADS was designed and built to enable the monitoring of change in performance as a result of changes in different design variables. The test facility is equipped with a flow loop, a data acquisition

system, and associated instrumentation to measure different parameters that will indicate the hammer performance.

During the testing, the following parameters were monitored:

(a) Impact Frequency
(b) Impact Velocity
(c) Instantaneous Pressures in the Upper and Lower Chambers
(d) Bit Rotation

As a result of this testing, appropriate modifications were incorporated into SPADS to fulfill the following objectives:

(i) Optimal sizing of the upper and lower chambers and control of the charging and discharging cycles for air from these chambers in order *to maximize the impact energy and the operating frequency*, and

(ii) Optimal distribution of the piston's kinetic energy between the linear and the rotational subsystems, in order *to ensure adequate bit rotation under extreme conditions of torque.*

2. Field Testing

A number of field tests were included under the scope of this project. The *initial* objective of the tests is to demonstrate the ability of the system to drill straight through hard rock at competitive penetration rates and independent of the drill string rotation.

During the year of 1994 a total of five field tests were conducted in West Virginia and West Texas to optimize and tool harden the rotational hammer itself. A number of problems ranging from tool design to operation procedures were encountered. The causes of failure and remedies adopted at the end of individual field tests are documented in Table 1.

While the drilling machine proved its ability to drill at a penetration rate (ROP) exceeding 90 feet per hour without rotating the drill string, it also showed its sensitivity to excessive weight on bit (WOB). Drilling at these straight hole field tests was halted after 40 to 110 feet during each test due to the stalling of the piston. This stalling is blamed mostly on the extreme rotational resistance torque which the bit has to overcome when too much weight is applied on the bit. A couple of new bit face designs are being implemented in an attempt to lower the torque under extremely high WOB conditions.

Additional lab testing was needed to better understand the magnitude of the torque required to rotate the bit during the drilling operation and to understand the associated circumstances which produce reasonably low torque at times and extraordinarily high torque at others, as observed in the field tests.

3. Additional Lab Testing

At Smith International, we rigged up a method for allowing us to actually drill on different formations. We drilled on hard rock (granite) as well as softer rock (limestone) using a forklift with an attempt to study the bottomhole patterns in different formations during drilling. The forks were loaded with collars of different weights to study the effect of WOB on the magnitude of the torque. A torque sub was designed and fabricated to measure the torque encountered during actual drilling conditions.

The study revealed that SPADS generates sufficient impact energy to drill in hard as well as soft rock; however under extreme conditions

Table 1. Results from the Field Testing

TEST #	FOOTAGE DRILLED	CAUSE OF FAILURE	REMEDY
Test 1	109 ft	Piston broke due to grinding cracks; Ceramic balls fractured due to sharp edges	Better quality control
Test 2	46 ft	Sand invasion	Install spring at check valve
Test 3	50 ft	Interference of bearing due to temperature gradient	Better thermal conducting material
Test 4	91 ft	Hammer stalled in dead band due to high torque	Divert more energy for rotation
Test 5	110 ft	High torque in formation changes	New low-torque bit designs

of loading, the hammer stalled as a result of a drastic increase in the torque on bit. The effect was especially notable in softer formations like limestone, where high WOB (approximately 8,000 lbs.) caused the bit to bury itself into the formation. The lack of a refined weight control technique prompted us to conduct additional testing at Sandvik Rock Tools, Inc.

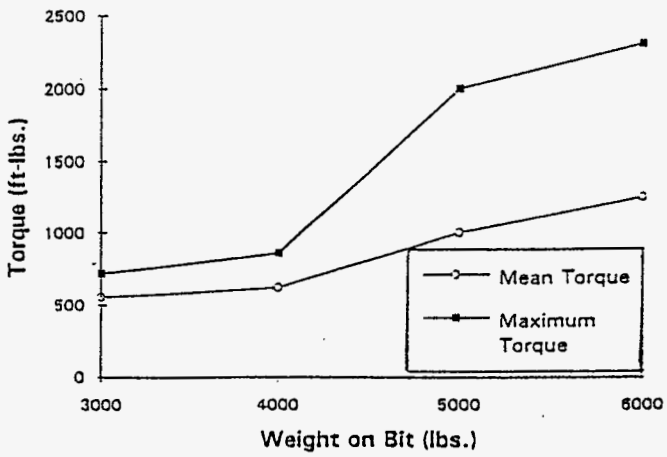


Figure 1. Effect of WOB on Torque

The facility at Sandvik is routinely employed for testing the performance of conventional down-the-hole hammers. The facility is equipped with a hydraulic hold down system that allows a better control of the WOB. A series of tests were conducted at Sandvik at different line pressures by varying the weight on the bit. Three different formations were tested viz., granite, limestone, and sandstone.

The results indicated that there is an optimum WOB at which the torque is reasonably low. If WOB is lower than the optimum value, the hammer has a tendency to remain open, causing a reduction in both frequency and ROP. On the other hand, an increase in WOB above the optimum is usually always accompanied by an increase in torque and a decrease in the ROP. With an increase in torque, more energy must be imparted to the rotary motion rather than the linear motion, causing a reduction in impact velocity and therefore also the ROP. The effect of WOB on the torque is shown in Figure 1. The optimum WOB in this case is in the range of 3,000-4,000 lbs, when the line pressure is 200 psi. Any increase in WOB results in a corresponding increase in the torque as well.

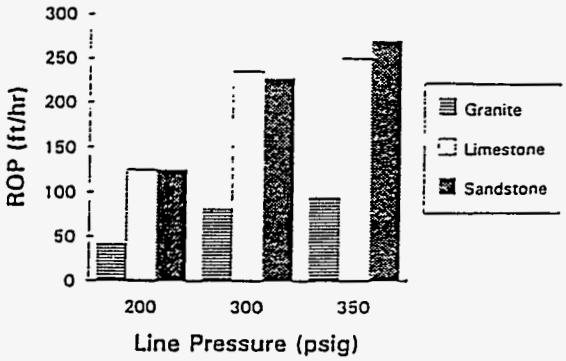


Figure 2. Hammer Performance in Different Formations

The performance of the hammer in different formations is shown in Figure 2. The tests were performed at three different line pressures viz., 200, 300, and 350 psig at the optimum WOB. There is a significant increase in the ROP in soft formations like limestone and sandstone. However, the torque encountered under identical conditions of line pressure and WOB is nearly the same in all the formations. Stalling of the hammer was not possible in these tests, since the maximum WOB that could be applied was limited to 6,000 lbs due to the capacity of the test rig.

FUTURE WORK

The following changes will be incorporated during the next straight hole field test scheduled for mid April:

(1) A better method of WOB control in the field tests e.g., pull down rigs

(2) Continuous monitoring of the WOB and torque

(3) Low torque bits to reduce the sensitivity of the hammer performance to WOB: redesign bit face to improve the rock to cutter interface. More and smaller diamond inserts are placed close together to provide better protection for the gage row.

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