

**Optimization of Deep Drilling Performance –
Development and Benchmark Testing of Advanced Diamond Product
Drill Bits & HP/HT Fluids to Significantly Improve Rates of Penetration**

Topical Report

Reporting Period Start Date – October 1, 2002

Reporting Period End Date – September 30, 2003

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Report Date – October, 2003

DOE Award Number – DE-FC26-02NT41657

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ABSTRACT

This document details the progress to date on the OPTIMIZATION OF DEEP DRILLING PERFORMANCE – DEVELOPMENT AND BENCHMARK TESTING OF ADVANCED DIAMOND PRODUCT DRILL BITS AND HP/HT FLUIDS TO SIGNIFICANTLY IMPROVE RATES OF PENETRATION contract for the year starting October 2002 through September 2002.

The industry cost shared program aims to benchmark drilling rates of penetration in selected simulated deep formations and to significantly improve ROP through a team development of aggressive diamond product drill bit – fluid system technologies. Overall the objectives are as follows: Phase 1 – Benchmark ‘best in class’ diamond and other product drilling bits and fluids and develop concepts for a next level of deep drilling performance; Phase 2 - Develop advanced smart bit-fluid prototypes and test at large scale; and Phase 3 – Field trial smart bit –fluid concepts, modify as necessary and commercialize products.

Accomplishments to date include the following;

4Q 2002

- Project started
- Industry Team was assembled
- Kick-off meeting was held at DOE Morgantown

1Q 2003

- Engineering meeting was held at Hughes Christensen, The Woodlands Texas to prepare preliminary plans for development and testing and review equipment needs.
- Operators started sending information regarding their needs for deep drilling challenges and priorities for large-scale testing experimental matrix.
- Aramco joined the Industry Team as DEA 148 objectives paralleled the DOE project.

2Q 2003

- Engineering and planning for high pressure drilling at TerraTek commenced.

3Q 2003

- Continuation of engineering and design work for high pressure drilling at TerraTek.
- Baker Hughes INTEQ drilling Fluids and Hughes Christensen commence planning for Phase 1 testing – recommendations for bits and fluids.

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INTRODUCTION

The industry cost shared program aims to benchmark drilling rates of penetration in selected simulated deep formations and to significantly improve ROP through a team development of aggressive diamond product drill bit – fluid system technologies. TerraTek has assembled a team of Industry and Academic contributors who are recognized leaders in a) hostile environment drilling operations, b) engineering development and large-scale testing, c) downhole tool engineering and supply, d) mechanics and rock cutting characterization, e) rig pump manufacturer, and f) commercial experience. Objectives include: Phase 1 – Benchmark ‘best in class’ diamond and other product drilling bits and fluids and develop concepts for a next level of deep drilling performance; Phase 2 - Develop advanced smart bit-fluid prototypes and test at large scale; and Phase 3 – Field trial smart bit –fluid concepts, modify as necessary and commercialize products.

EXECUTIVE SUMMARY

Background

TerraTek proposed to develop and test innovative bits / new products in the ‘Wellbore Simulator’. Confining and overburden stresses are applied to selected rock samples and borehole pressures / hydraulics can be controlled. Weight-on-bit is applied with a servo-controlled system and rotary speed is controlled with variable speed direct drive motors, 5-speed transmission and standard oil-field rotary table. High-pressure fluid ends on the mud pump will facilitate drilling at pressures in excess of 10,000 psi. Computer aided engineering practices will be used by the bit supplier to develop and design features important to the improvement of ROP at great depths. The work proposed to benchmark performance and provide bit developments first for a 6 to 8-1/2” diameter range. New mud pump developments have increased rig capabilities to 7500 psi and have increased capability to 2200 and 3000 horsepower. The addition of a mud pump company as a team member strengthens both the proposed development program and also the future ability of the domestic rig fleet to drill beyond depths of 16,000 feet and have sufficient hydraulics. John Shaughnessy, BP’s Senior Drilling Engineering for the Tuscaloosa trend, noted at the March 2001 Deep Trek Workshop that “over 50% of rig time is spent in the last 10% of the hole” and the operator has “high interest in improving ROP deep”.

The relevance of benchmarking downhole tool performance at high pressures and developing innovative impregnated bit cutting structures is highlighted by the technical challenges operators are facing. Large-scale laboratory testing of downhole drilling tools at simulated deep conditions has a proven track record in determining actual performance and identifying crucial design parameters. The most familiar work in the industry relates to testing of PDC drill bits using recorded performance data in the engineering designs on innovative new products. In fact most PDC bit developments historically have come from large-scale laboratory testing. DEA Project 90 conducted drilling performance tests at 7,500 psi borehole pressure. This work proposes a next step in the ability to develop new

products for commercialization; the testing will be performed at pressures in excess of 10,000 to 12,000 psi, a capability unique to the TerraTek laboratory drilling facility. In the case of solving deep drilling vibration problems, tests in a large-scale laboratory environment are preferred, as precise control of operating conditions is needed along with high frequency acquisition of data not possible in field wellbore environments.

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3Q 2003

- Continuation of engineering and design work for high pressure drilling at TerraTek.
- Baker Hughes INTEQ drilling Fluids and Hughes Christensen commence planning for Phase 1 testing – recommendations for bits and fluids.

Plans for 4Q 2003

- Pre-Drilling Engineering Meeting with Team in Houston planned for November 19, 2003. Test conditions, bit types and drilling fluids will be selected.

EXPERIMENTAL

Experimental work will commence 4Q 2003 after long planning and engineering time spent summer 2003. High-pressure capabilities are nearly in place and will be ready to perform the testing as proposed. For reference the original matrix of tests included the following:

TEST MATRIX-DEEP DRILLING PROGRAM				
TEST NUMBER	BIT	ROCK SAMPLE	MUD TYPE	TEST OBJECTIVE
1	R 1	COMBO 1	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud A with Bit R1
2	R 2	COMBO 1	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud A with Bit R2
3	D 1	COMBO 1	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud A with Bit D1
4	D 2	COMBO 1	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud A with Bit D2
5	R 1	COMBO 2	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 2 and Mud A with Bit R1
6	R 2	COMBO 2	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 2 and Mud A with Bit R2
7	D 1	COMBO 2	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 2 and Mud A with Bit D1
8	D 2	COMBO 2	MUD A	Evaluate the ROP response at simulated deep depths in rock types of COMBO 2 and Mud A with Bit D2
9	R 1	COMBO 1	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit R1
10	R 2	COMBO 1	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit R2
11	D 1	COMBO 1	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit D1
12	D 2	COMBO 1	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit D2
13	R 1	COMBO 2	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and

				Mud B with Bit R1
14	R 2	COMBO 2	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit R2
15	D 1	COMBO 2	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit D1
16	D 2	COMBO 2	MUD B	Evaluate the ROP response at simulated deep depths in rock types of COMBO 1 and Mud B with Bit D2
NOTE: R1 AND R2 REPRESENT THE CURRENT BEST PRACTICES ROLLER CONE BITS				
D1 AND D2 REPRESENT THE CURRENT BEST PRACTICES DIAMOND BITS				
COMBO 1 IS A COMBINATION SAMPLE OF TWO SUITABLE ROCK TYPES CONSISTENT WITH DEEP DRILLING STRATA				
COMBO 2 IS A COMBINATION SAMPLE OF TWO DIFFERENT ROCK TYPES CONSISTENT WITH DEEP DRILLING STRATA				

RESULTS AND DISCUSSION

Q4 2002

Kick-off meeting at DOE, Morgantown December 17, 2003



*An Industry / DOE Program to “Develop and Benchmark
Advanced Diamond Product Drill Bits and HP/HT Drilling Fluids
to Significantly Improve Rates of Penetration”*

Optimization of Deep Drilling Performance

*Team: William Gwilliam (Department of Energy/NETL);
Arnis Judzis, Alan Black (TerraTek);
Allen Sinor, Redd Smith (Hughes Christensen);
Ron Bland (Baker Hughes INTEQ Drilling Fluids);
Bud Trammel, Mark Reese (National Oilwell);
Tim Travis (ExxonMobil); Gary Collins (ConocoPhillips)
Jim Mullen (Marathon); Richard Harting (Aramco);
Rich Reiley (BP America); Stefan Miska (University of Tulsa)*

Meeting at NETL Morgantown, December 17, 2002



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*This program aims to benchmark drilling rates of penetration
in selected simulated deep formations and to significantly
improve ROP through a team development of aggressive
diamond product drill bit - drilling fluid system technologies.*

Context
Team Roles & Project Management
Technical Objectives
Scope of Work
Budget Overview & Schedule
Looking Forward



Context

- **Economic Benefit**
 - Domestic developments in drilling tools, fluids, and testing
 - Great potential for increased activities in deep gas plays
- **Drilling Performance**
 - Diamond product bit applications for increased rate of penetration
 - Directional drilling applications
 - Higher temperature drilling fluids
- **Target Markets**
 - Gas, deep gas plays
 - Mid continent, Overthrust, Appalachian Basin, etc.
- **Advantages in large-scale experiments in wellbore simulator –**
 - Economics (start-up with high day rates difficult with prototype tools)
 - Ability to compare tools and performance directly
 - Test rig ‘height’ offers easy access to tools/handling
 - Drilling conditions are carefully controlled & measured (data acquisition)
 - Equipment can be modified and retested
 - Provides wide range of experiments simulating deep field conditions -
flow rates, pressure, rock types, rotary speed, fluid etc.

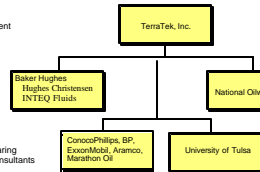
Team Roles and Project Management

Project Organization

Project Management

Industry Cost Sharing Suppliers

Industry Cost Sharing Operators and Consultants



Technical Objectives

- **Characterization of applications –**
Determine deep drilling performance issues related to bits and fluids in operators' areas of challenge and commence with suppliers engineering evaluations of promising concepts.
- **Benchmark performance of 'best-in-class' products –**
Conduct full-scale drilling tests in TerraTek's Wellbore Simulator at high pressures in hard rock to reveal deficiencies and design features important for improved deep drilling performance.
- **Develop aggressive diamond product bits and fluids to improve ROP –**
Test and improve significantly drilling performance via emerging and newly developed drill bits and fluid systems.
- **Commercialization and field deployment –**
Test and deploy via field testing on operator wells prototype bits and fluids developed as a result of the prior year effort.

Scope of Work

- **Phase 1 Feasibility Concept Definition –**
Assess deep drilling applications requiring tool/fluid development
Design, engineer, and plan HP drilling program
Perform full-scale drilling tests
Benchmark bit/fluid system performance
Transfer technology
- **Phase 2 Prototype Development and Testing –**
Design and construct prototype bits and fluid systems
Test novel bit/fluid technologies at high pressures
Transfer technology and review progress against plan
- **Phase 3 Demonstration and Commercialization –**
Obtain Industry Advisors input for field trials
Optimize drilling conditions through large-scale testing
Perform field tests on developed systems
Finalize 'lessons learned' in this program
Finalize commercialization effort
Prepare final report on 'Deep Drilling Optimization'

Budget Overview

Total Program \$2,929 k; DOE share \$1,692 k, Cost sharing \$1,237 (42%)

- Feasibility Concept Definition
- Prototype Development and Testing
- Demonstration and Commercialization

TOTALS

DOE, \$k	Cost Share, \$k
704	259
571	368
417	610
1,691	1,237

Looking Forward

- TerraTek plans to convene team in Houston (probably end January 2003) to finalize test conditions and review bit and fluid developments

TerraTek
Baker-Hughes (Hughes Christensen & INTEQ)
National Oilwell
University of Tulsa
Operators (BP, Marathon, ConocoPhillips, ExxonMobil, Aramco)

- Upgrades to pumping and pressure capability will be necessary beginning 2003.
- Outstanding issues - pumping capacity vs. pressure - bit size determination. TerraTek recommends that input from the Houston planning and engineering meeting help decide this.
- BP was particularly keen to conduct possible field trials of bits and fluids in 2005.

Example Industry Support



An Industry / DOE Program to "Develop and Benchmark
Advanced Diamond Product Drill Bits and HP/HT Drilling Fluids
to Significantly Improve Rates of Penetration"



- Closure
- Questions & Answers



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BP Exploration Deep Drilling Challenge – Rich Reiley (Industry Perspective)

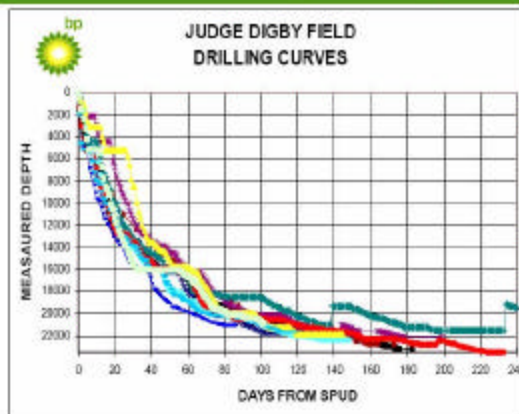
Deep Hard Rock Drilling Challenge



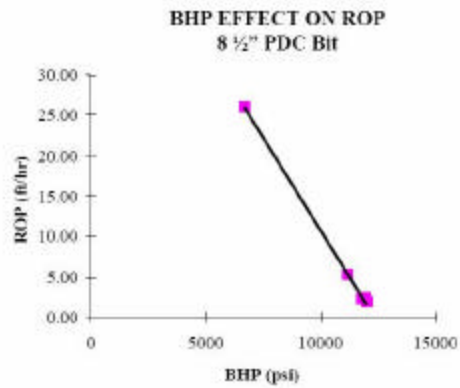
- PDC Bits
 - Drill too slow, dull too fast
- Electronics
 - Cook in HPHT environment
- Drilling Fluids
 - Hard to pump, high ECD, trap gas

Key to solving the deep hard rock drilling challenge is understanding the problem.

Deep Hard Rock Drilling Challenge



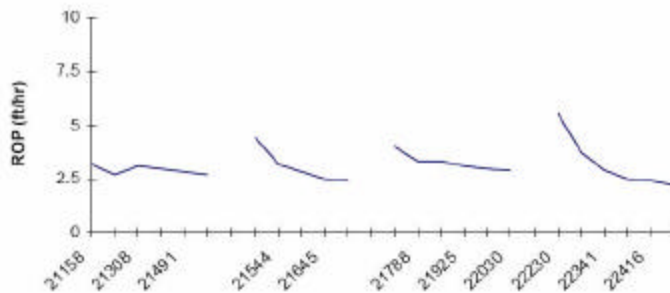
Deep Hard Rock Drilling Challenge



Deep Hard Rock Drilling Challenge



- Parlange # 7, 6" section:
- ROP drop worse with more worn bits;
 - step change in ROP from worn to new bit



Deep Hard Rock Drilling Challenge



5 7/8" Bit
8, 11, 13mm cutters
19,087' to 19,556'
Drilled 469 feet
111 hours on PDM
WOB 2K to 6K
ROP 4.2 (2- 10)
18,500 psi BHP

Pulled for Low ROP

OCT 17 2002

Deep Hard Rock Drilling Challenge



Key to solving the deep hard rock drilling challenge is understanding the problem.

15,000 psi at 400 deg F Deep Trek tests?

Q1 2003

Update for DOE project manager January 22, 2003

Accomplishments to date (contract started October 1, 2002)

- A Kick-off meeting was conducted at NETL's Morgantown facility on December 16, 2002. Baker Hughes and BP provided industry perspectives.
- The project has advanced the concept of combined input from both a bit and drilling fluid supplier to consider DeepTrek developments as a system - 'smart fluid / bits' for enhanced performance. Baker Hughes Inteq's Ron Bland met with TerraTek staff in Salt Lake City.
- Industry cost sharing accelerated with ARAMCO's interest in aggressive bits and willingness to join the team with funds. Originally proposed as DEA 148, ARAMCO's interests now parallel the DOE 'team' objectives.
- National Oilwell is currently studying options for pumping at high pressures, awaiting further refinement of test 'matrix'. They have already built some prototype high pressure pumping systems for deep applications and are evaluating progress in various projects on the merits of their systems.
- A February 13 technical meeting has been scheduled at Hughes Christensen in Houston to deliberate bit size and hydraulics best suited for first year's benchmarking and development of prototype equipment. This step will be crucial to focus engineering and design expenditures by Baker Hughes thus will form the basis of minimum expected performance as the program progresses. Commercial availability of the bits and fluids (and accelerated development by domestic competitors) will have the greatest immediate impact on the oil and gas industry.

Engineering kick-off meeting February 13, 2003



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Meeting at Hughes Christensen, February 13, 2003



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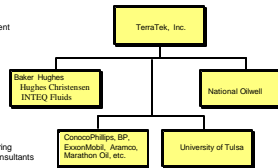
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Status

- TerraTek convening team in Houston to finalize test conditions and review bit and fluid developments (13 February 03)

TerraTek
Baker-Hughes (Hughes Christensen & INTEQ)
National Oilwell
University of Tulsa
Operators (BP, Marathon, ConocoPhillips, ExxonMobil, Aramco ,
others pending)

- Upgrades to pumping and pressure capability will be necessary beginning 2003.
- Outstanding issues - pumping capacity vs. pressure - bit size determination. TerraTek recommends that input from the Houston planning and engineering meeting decide this.

Activities to date *(contract started October 1, 2002)*

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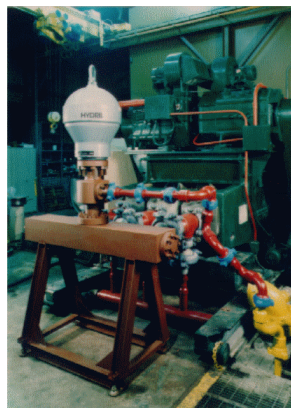
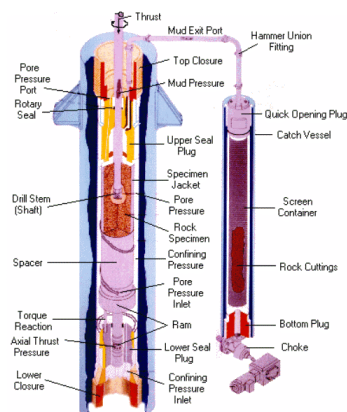
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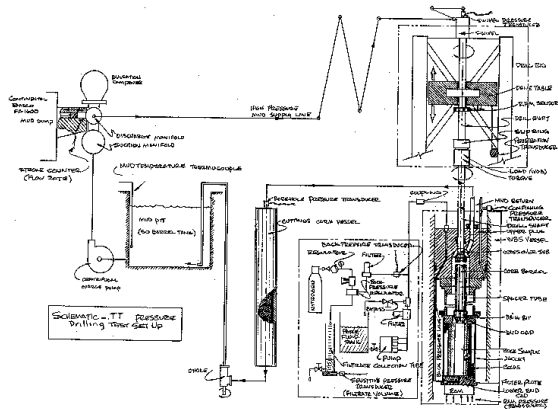
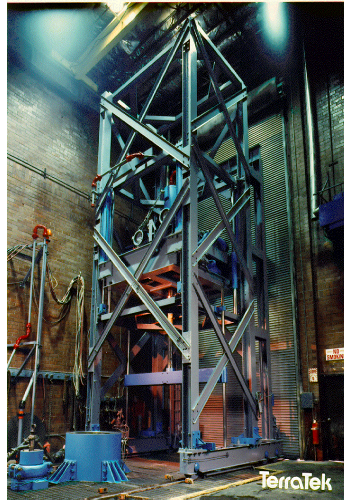


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TerraTek Preparations for DeepTrek High Pressure Drilling Tests

Equipment Upgrades Testing Considerations





Equipment Upgrades

- Rock Preparation
- Drilling Fluid Cooling
- High Pressure Choking
- High Pressure Mud Sealing and Pulsation Dampening
- High Pressure Pumping Capacity
- Safety and Operational Features

Rock Preparation

- Rock Size
 - 15 1/2" Dia. x 36" long for 6 1/2" bits
 - 17 1/2" Dia. x 36" long for 8 1/2" bits
- End Caps and Jackets
 - Thicker jacket material
 - Machine o-rings in end caps
 - Improved jacket sealing and clamping

Drilling Fluid Cooling

- Expand existing heat exchanger for mud cooling
- Mix larger batches of mud i.e. 125 bbl vs 50 bbl
- Modify square mud pit with corner jetting
- Rapid pressurization of vessel to minimize mud shearing/heating time

High Pressure Mud Choking

- Multiple fixed bean choke manifold and variable choke
- Downstream piping protection
- High pressure cuttings collection vessel
- High pressure piping
- High pressure Chiksan fittings

High Pressure Mud Sealing and Pulsation Dampening

- Mud Sealing
 - Rotary seals and back-ups spares
 - Swivel seals, back-ups and wash-pipe spares
 - Mud pump seals, back-ups and plunger spares
 - Mud pump valve seats and seals spares
- Pulsation Dampening
 - Test existing Hydril experimental “Silicone” dampener
 - Rent high pressure pulsation dampener

High Pressure Mud Pumping Capacity

- TerraTek high pressure fluid ends to supply 180 gpm
- National high pressure pump to supply 110 gpm for 6 1/2” bit or 290 gpm total
- National high pressure pump to supply 220 gpm for 8 1/2” bit or 400 gpm total
- National to supply W-2250 plunger pump
- Pump driver in question?:
 - 2200 or 1100 HP depending on bit size
 - Options:
 - 2200 HP require TT to seek additional funding
 - 1100 HP require National to help and TT to rent or lease driver from National

Safety and Operational Features

- Safety
 - Refurbish and calibrate pressure relief valves
 - Mechanical pressure gage back-up to instrumentation
 - Static pressure check all systems
- Operational Features
 - Remote operation of all equipment
 - Communication system for coordination of two pumping systems
 - Remote video monitoring of high pressure areas

Testing Considerations

- Bit size/Rock size
- Rock Types
- Pore Pressure Control for Permeable Rocks
- Borehole Pressure-10,000 or 12,000 psi
- Phase 1-16 tests
- Phase 2-16 tests
- Phase 3-8 tests
- Bit Selection
 - Bit type
 - Bit hydraulics
- Mud Selection
 - Mud type
 - Mud density
- Operational range
 - WOB, RPM, flow rate,
 - borehole pressure/or pressures

MEETING MINUTES

DeepTrek DOE/Industry Program

“Optimization of Deep Drilling Performance”

Engineering Meeting 13 February '03 with Operators and Suppliers

Executive Summary

ATTENDEES

At Hughes Christensen offices in The Woodlands;

Hughes Christensen; Redd Smith, Allen Sinor, Rolf Pessier, Brian Miller

National Oilwell; Jerry Johnson

BP America, Rich Reiley

Marathon, Jim Mullen, II

TerraTek, Arnis Judzis, Alan Black

Regrets;

ARAMCO, ConocoPhillips, ExxonMobil, INTEQ Drilling Fluids, University of Tulsa;

Contacts with other interested operators such as ChevronTexaco are in progress.

MEETING OBJECTIVES

The meeting objectives were as follows:

1. Roll out the Deep Drilling Optimization program to team members
2. Determine requirements for drilling with 6” and 8-1/2” range bits
3. Develop action plan for getting operator deep drilling challenges with emphasis on geological settings, rock types and conditions

SUMMARY (presentation material and project information is attached)

Overview presentation “Optimization of Deep Drilling Performance” (A. Judzis)

Discussion points: Operators will supply information on the assessment of their deep / hard rock drilling challenges. Information related to rock types, geological setting and conditions would be

used to finalize the test matrix (covered in the 'round table discussion'). Rolf Pessier brought up siltstones (fine grained, laminated shale) as a complement to tests in sandstones. Some characterization of rock samples will be required. Roles and responsibilities were covered along with industry contributions to the program. Phase 1 work runs through end September 2003.

Presentation on "Testing Considerations" (Alan Black)

Discussion points: Most discussion covered pumping requirements for testing of 6" vs. 8-1/2" range bits. National Oilwell (Jerry Johnson) will work with Bud Trammel and Alan Black to look at drives for the high pressure pumps. Good discussion ensued about power requirements for various flow rate and rules-of-thumb for various bit sizes. Hughes Christensen staff noted that the 6" bit sizes were actually 5-7/8" and 6-1/8" bits. Designing bits that would perform at depth (harder rocks, pressure, etc.) for this range is challenging but doable for delivery of DeepTrek objectives. Comments centered on replicating what is going on in the field and determining what causes slow penetration rates. Some specific questions about TerraTek's equipment such as chokes and dampeners were also covered.

'Round table' discussion of program

Bit size – BP's Tuscaloosa applications use 5-7/8" bits. Jim Mullen (Marathon) discussed some 8-1/2" applications to a depth of 18,000. Aramco is using 5-7/8" sizes. Consensus developed towards 5-7/8" and 6-1/8" standard sizes. Brian Miller noted that the challenges are somewhat less for the 8-1/2" size, thus DeepTrek objectives could definitely be met with the development and testing of the nominal 6" sizes (5-7/8" and 6-1/8"). Baseline bit performance was also discussed, opening up the possibility of running a roller cone bit or other.

Flow rates – Lower flow rates (20-30 gal/in bit) of 150 to 180 gpm sometimes occurs in the field; benchmark what happens at lower flow rates and then 240 to 300 gpm (40-50 gal/in bit) desirable for performance evaluation with improved hydraulics.

Rock types and stress conditions – Operators will provide some details on key formations representing deep drilling challenges (16,000 ft or deeper) that can be addressed by this program. Sandstones, siltstones, carbonates, and bromides were suggested for further evaluation of importance.

Mud weight and type(s) – Suggestions centered on various mud weights depending upon the greatest challenges. Rolf Pessier suggested duplicating field conditions expected insofar as possible. BP's Rich Reiley endorsed that and added that factors affecting performance improvements over baselines should be understood. Ron Bland at INTEQ will be working with the team on mud types and their development. Solids control will be important.

Other conditions – Allen Sinor presented some information about new vs. 'dull' bit performance. Consistency in procedures should prevail as testing is performed on new designed bits.

Testing matrix – The first phase of the program will benchmark bit / fluid performance in 16 high-pressure tests. The following variables are to be considered as information from the operators on formation properties come in;

1. Bit type – impreg diamond, PDC, perhaps natural diamond, baseline roller cone?
2. Rock types – sandstone(s), siltstone, limestone, hard 'bromides'
3. Drilling fluids – types, solids content, etc.
4. Drilling and other parameters – pressures, flow rates / hydraulics, WOB, rpm, etc.

Before closing the good discussion, Hughes Christensen recommended that electronic files of information be set up in order to facilitate information transfer. The group also agreed to meet in approximately 1 to 2 months for finalizing program needs before testing mid to late summer.

ACTION ITEMS

1. Operators are requested to provide information sufficient to support specific deeper / hard rock applications requiring significant performance improvements from this deep drilling development project. Please provide information about the geological setting as well as identifying specific rock types. I would be grateful for this information by March 12, 2003. (BP – one area will be Tuscaloosa, Aramco – I have already written Drew Hembling, ConocoPhillips – Gary Collins could you provide examples?)
2. TerraTek personnel and Hughes Christensen will confer with Ron Bland of INTEQ Drilling Fluids on recommendations for 'best-in-class' testing followed by the development of other fluids for DeepTrek applications.
3. Alan Black and National Oilwell (Bud Trammel) to discuss pump drive requirements.
4. A. Judzis to assemble information related to operators' 'deep drilling applications' and schedule next meeting as soon as possible.

Summary by A. Judzis, Executive Vice President TerraTek 26 February '03

Q2 2003

Preparing TerraTek's high pressure drilling system

Q3 2003

.....
September, 2003

INPUT FOR HUGHES CHRISTENSEN AND BAKER HUGHES INTEQ FOR DEEPTREK TESTING PROGRAM RECOMMENDATIONS AT TERRATEK

Here is information I have to date on applications for 'DeepTrek' type of tests. I used the 'cut and paste' technique.

BP COMMUNICATION March 6, 2003 (more information coming during September, 2003 from Kent Corser and Jim Wellings)

From: "Reiley, Richard H.", INTERNET:reileyr@bp.com
 To: "Sanders, James M", INTERNET:James.M.Sanders@bp.com
 CC: "Winters, Warren J", INTERNET:winterwj@bp.com
 "Storaune, Anders (BP)", INTERNET:StorA5@bp.com
 "Holt, Charles A", INTERNET:HoltCA@bp.com
 "Robinson, Steve W", INTERNET:RobinsSW@bp.com
 "Abbassian, Fereidoun", INTERNET:abbassif1@bp.com
 "Armagost, W Kenneth", INTERNET:ArmagoKW@bp.com
 "Reese, James C", INTERNET:reesejc@bp.com
 "Arnis Judzis", ArnisJudzis
 Date: 3/5/03 9:50 AM

RE: DeepTrek Research Handover

I have given Arnis Judzis of TerraTek your name as point contact for Tuscaloosa geologic and drilling condition information. DeepTrek will test small diameter bits at high confining pressures. To meet BP's needs, it is important to select test rock samples most closely resembling actual Tuscaloosa drilling conditions. I recommend one or two tests use shale/sand/shale test samples. The remainder of the test samples will be homogeneous rocks. All time spent in gathering information can be credited towards BP's in-kind contribution to the project.

Needed information for 6" holes section in HPHT well:

- 1) mud property reports
- 2) detailed rock descriptions and rock properties
- 3) sonic transit times for sands and shales

Question? Can Tuscaloosa provide TerraTek with two used 5 7/8" PDC bit with little wear and minimum cutter damage that were pulled for low ROP? The mud log records of torque, WOB, drilling assembly, ROP, etc will also be needed. These bits will be lab tested to drill rocks under high confining stresses. From these test, it may be possible to determine why a bit with very little wear had to be pulled for low ROP. Providing used bits and detailed operating reports is an inexpensive way to increase our knowledge of deep Tuscaloosa drilling challenges. My guess is that the test may show bit balling as a major cause of low ROP, but this is just guess until we do the tests. We can also determine how much power is required to drill, i.e. bit torque vs. ROP for these used bits and compare to new bits.

Richard H Reiley, Upstream Technology Group
Houston, Texas
281 366 5189
Hard Rock Drilling Implementation Team
Expandable Tubulars, Casing Drilling, Underbalanced Drilling and Completions

MARATHON COMMUNICATION March 14, 2003

From: "Mullen, II, Jim", INTERNET:JCMullen@MarathonOil.com
To: "Arnis Judzis", ArnisJudzis
Date: 3/14/03 4:15 AM
RE: (UCS added) RE: DeepTrek Drilling Performance Engineering Meeting Minutes

Arnis - (UCS added to table)

The area of greatest interest for Marathon's current deep, hard rock drilling programs is in the Arbuckle trend of Oklahoma, Grady & Stephens Counties. We drill the deep sections (15,000' - 20,00') with 11 to 12 ppg water based mud. BHT is ~240 deg.

Our most recent well, the Fox Alliance 9-3, was our best drilling performance in the field - good success with Hughes new HedgeHog style impreg bit. Formations of interest:

Formation	Lithology	UCS (psi)
Bromides	Limestone, Shale, & Sandstones	15,000-26,000
McLish	Sandstones & Shales	8,000-26,000
Oil Creek	Sandstones, Shales, and some Limestone	10,000-26,000
Joins	Limestone, w/ some Shale & Sandstones	15,000-26,000
Arbuckle	Limestone & Dolomite	15,000-35,000

Let me know if you need any additional information at this time.

Thanks - Jim

ARAMCO COMMUNICATIONS March 23, 2003

DOE and JIP Geological and Rock Descriptions Richard
Harting#INTERNET:richard.harting@aramco.com

Arnis Judzis,

Presently Aramco only has one formation that we consider a "hard rock" drilling candidate. I have attempted to characterize the Lower Permian Unayzah formation below:

Formation:	Unayzah
Depth Range:	13,500' - 16000'
Temperature Range:	260 - 350 degrees F
Lithology:	Silica cemented sandstone (up to 98% qtz)
Average Porosity:	7.9%
Average Permeability	11.5 mD
Pore Pressure Grad.	0.45 - 0.61 psi/ft
UCS:	17,000 - 26,000 psi
Internal Friction Coeff:	1.13 - 1.30

The Unayzah may be similar to very tight, silica-cemented parts of the Tensleep Formation in the USA, although I have no rock property data from the Tensleep upon which to base that comparison.

Let me know if you need more information.

Thanks and best regards,
Dick

-----Original Message-----

From: Arnis Judzis [mailto:ArnisJudzis@compuserve.com]
Sent: Saturday, March 15, 2003 1:44 AM
To: Richard R Harting
Cc: Arnis Judzis
Subject: DOE and JIP Geological and Rock Descriptions

Dick,
Have you made any progress on getting us some information?

Regards,
Arnis Judzis
TerraTek

TELEPHONE COMMUNICATION WITH GARY COLLINS AT CONOCOPHILLIPS March 5, 2003

Gary's telephone number is (281) 293-6969

His formations of interest include;
Granite and fractured granite like Vietnam 25-35 ksi UCS
Some deep Gulf of Mexico shale sand sequences

East Texas, Tenseep, Cotton Valley, and from Marathon experience Nugget [Wyo]

Letter to William Gwilliam 17 September 2003 with status report on TerraTek pressure drilling capabilities

To: William Gwilliam, INTERNET:william.gwilliam@netl.doe.gov
CC: Arnis Judzis, INTERNET:judzis@terratek.com
CC: Alan Black, INTERNET:ablack@terratek.com
From: Arnis Judzis, INTERNET:ArnisJudzis@compuserve.com
Date: 9/17/2003, 1:19 PM
Re: TerraTek DeepTrek Project

William,

Per your discussion with Alan, this is a request for an extension of time for conducting the first phase of the DeepTrek Project entitled "Improve Deep Drilling Performance". Our estimate for completing these tasks is end April 2004.

Alan has briefed you verbally on this and I have attached his written description of laboratory preparations to date. The issues significant to progress are high-pressure upgrades to TerraTek's facilities and potential for delay from National Oilwell. On the latter issue, Alan will look at alternatives to additional pump rates and brief you directly on this.

You also inquired about the possibility of additional bit(s) in the program. This is rather interesting as we discussed in Morgantown some time ago. In order to better evaluate the possibility, I need your help in assessing whether there is a 'cost-sharing' component of the potential [other] bit that could offset any imposed lower contributions by Hughes Christensen. Currently HC has agreed to provide all of the needed engineering and bits for the testing matrix discussed in February of this year. In fact, Hughes Christensen would almost prefer more tests if it were possible to expand the matrix.

Best regards,

Arnis Judzis, Executive Vice President
TerraTek
judzis@terratek.com
(801) 584-2483

Status of Preparation for DeepTrek High Pressure Drilling Tests

(Note: Tasks below were outlined at 2/13/03 Project Kick-off Meeting)

Task	Status
<u>Rock Preparation:</u>	
-Thicker jackets	4 received, 2 in process
-Machine o-rings in end caps	Completed
-Improved jacket sealing and clamping	Partially completed
<u>Drilling Fluid Cooling:</u>	
-Expanded heat exchanger	Completed
-Set up large tank for 125 bbls of mud	Completed
-Pit jetting in corners	Completed
-Rapid pressurization of vessel	Completed
<u>High Pressure Mud Choking:</u>	
-Multiple fixed bean choke manifold and variable choke	Fixed chokes partly received Choke holders received Needs assembly
-Down stream piping protection	Parts completed Needs assembly
-High pressure cutting collection vessel	Final assembly now
-High pressure piping	Received, needs assembly
-High pressure Chiksan fittings	Received, needs assembly
<u>High Pressure Mud Sealing and Pulsation Dampening:</u>	
-Rotary seals and backups	Completed, need backups
-Swivel seals and backups	Completed, need backups
-Mud pump seals and backups	Completed, need b-backups
-Pulsation dampening Hydril experimental dampener	In house
-Pulsation dampening rental	Will address after first test
<u>High Pressure Mud Pumping Capacity:</u>	
-National Oil Well pump	Available
-Drive system for pump	Assessing used equipment market and availability
-Other rental pumps	Considering if National Oil Well effort not successful
<u>Safety and Operational Features:</u>	
-Refurbish and calibrate pressure relief valves	To be completed
-Mechanical pressure gage backup to instrumentation	Partially completed
-Static pressure check	To be completed
-Remote operation of all equipment	Completed
-Communication system to coordinate two pumps	Completed
-Remote video monitoring of high pressure areas	Partially completed

Coming up 4Q '03

Pre-Drilling Engineering meeting scheduled for November 19, 2003

To: Miles N Sweep, INTERNET:mns@chevrontexaco.com
To: William Gwilliam, INTERNET:william.gwilliam@netl.doe.gov
To: Alan Black, INTERNET:ablack@terratek.com
To: RW Bud Trammell, INTERNET:bud.trammell@natoil.com
To: Redd Smith, INTERNET:red.smith@hugheschris.com
To: Allen Sinor, INTERNET:Allen.Sinor@hugheschris.com
To: David B Young, INTERNET:david.young@inteq.com
To: Ron Bland, INTERNET:ron.bland@inteq.com
To: Tim Travis, INTERNET:tim.travis@exxonmobil.com
To: Richard R Harting, INTERNET:richard.harting@aramco.com
To: Kent Corser, INTERNET:corserk@bp.com
To: Jim Wellings, INTERNET:wellinj1@bp.com
To: Jim C Mullen, INTERNET:jcmullen@marathonoil.com
To: Gary J Collins, INTERNET:gary.j.collins@conocophillips.com
CC: Arnis Judzis, INTERNET:judzis@terratek.com
From: Arnis Judzis, INTERNET:ArnisJudzis@compuserve.com
Date: 10/30/2003, 12:05 PM
Re: Deep Drilling Performance DeepTrek Project Meeting 19 November

"Optimization of Deep Drilling Performance" DeepTrek Project Team:

Hughes Christensen has kindly agreed to host a project meeting at their facilities in The Woodlands on Wednesday November 19. Since our engineering meeting last February TerraTek has been upgrading its full scale drilling testing facility to accommodate high pressures. The meeting in February was a preparatory discussion covering 1) project goals, 2) request Industry Team input on certain deep drilling challenges, and 3) begin setting the testing program.

I believe we can cover most issues during the morning, thus I propose meeting be held at Hughes Christensen on November 19, 2003 from 9:00 AM to noon. Allen Sinor (281-363-6460) is our contact at Hughes Christensen. Addressees of this note may already know that the Drilling Engineering Association meeting for 4th quarter 2003 will be held on November 20 at BP's offices in Houston.

The meeting objectives will be as follows;

1. Update of facilities for the DeepTrek project (Alan Black, General Manager TerraTek)
2. Briefly review input to date on operator deep drilling challenges. I

have received some information from Marathon, BP, Aramco, and ConocoPhillips.

3. Finalize a testing program with sufficient detail so that Hughes Christensen and INTEQ Fluid can provide drilling bits and mud, respectively. Note that the group decided to use 5-7/8" and 6-1/8" bit sizes.
4. Sanction of testing program by DOE's project manager.
5. Closure and set schedule for TerraTek phase 1 testing.

We look forward to seeing you. I will send an updated agenda and information before the meeting.

Arnis Judzis, Executive Vice President
TerraTek
judzis@terratek.com
(801) 584-2483

CONCLUSIONS

- Task 1 project kick-off meeting with DOE personnel completed. An additional engineering meeting was held at Hughes Christensen February 13, 2003 to define testing goals and review deep drilling challenges. Input by Industry Team members on their assessment of deep drilling challenges largely complete. BP has provided additional information now on deep Tuscabosa drilling problems and review.
- Task 2 designs and engineering concepts for drilling at high pressure 80% complete. A pre-drilling meeting will be held November 19, 2003 to resolve any final issues.
- Task 3 will commence 4Q 2003 and is 4 months behind schedule. All large components are in place to proceed with high pressure drilling except pumping capacity for flow rate.
- Task 5 has started with a request by the DOE project managers and GTI to publish at GTI's February meeting.

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Garnier, A.J., and Van Lingen, N.H., “Phenomena Affecting Drilling Rates at Depth”, Petroleum Transaction, AIME, Vol. 216, 1959, pp. 232-239.

Maurer, W.C., “The ‘Perfect-Cleaning’ Theory of Rotary Drilling”, Journal of Petroleum Technology, November, 1962, pp. 1270-1274.

Feenstra, R., Van Leeuwen, J.J.M., “full-Scale Experiments on Jets in Impermeable Rock Drilling”, Journal of Petroleum Technology, March, 1964, pp. 329-336.