

**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, 2003

Reporting Period End Date – September 30, 2004

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Report Date – October, 2004

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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 2003 through September 2004.

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.

As of report date, TerraTek has concluded all major preparations for the high pressure drilling campaign. Baker Hughes encountered difficulties in providing additional pumping capacity before TerraTek’s scheduled relocation to another facility, thus the program was delayed further to accommodate the full testing program.

Accomplishments to date include the following;

Previously reported**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.

Current Report**4Q 2003**

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- TerraTek prepared a paper for publication at the upcoming GTI Gas Technologies Conference.
- One of the Industry Advisors, BP America, provided the project team with some information about deep drilling performance in Louisiana.

**1Q 2004**

- TerraTek presented a paper entitled “Optimization of Deep Drilling Performance” at the GTI Natural Gas Technologies Conference held 8-11 February 2004 in Phoenix, Arizona at the request of DOE.

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- Another engineering and planning meeting was held at Hughes Christensen May 25, 2004 to develop a test matrix after the early input by Industry Advisors on deep drilling applications and possible simulated downhole conditions.
- TerraTek completed internal preparations for its high pressure drilling equipment.

**3Q 2004**

- An update of the DeepTrek project was made to the 3Q 2004 meeting of the Drilling Engineering Association.
- The DOE and Hughes Christensen agreed to defer the DeepTrek project to early 2005 after Hughes encountered difficulties in delivering a new pumping unit before TerraTek’s scheduled move to a new facility in Salt Lake City.

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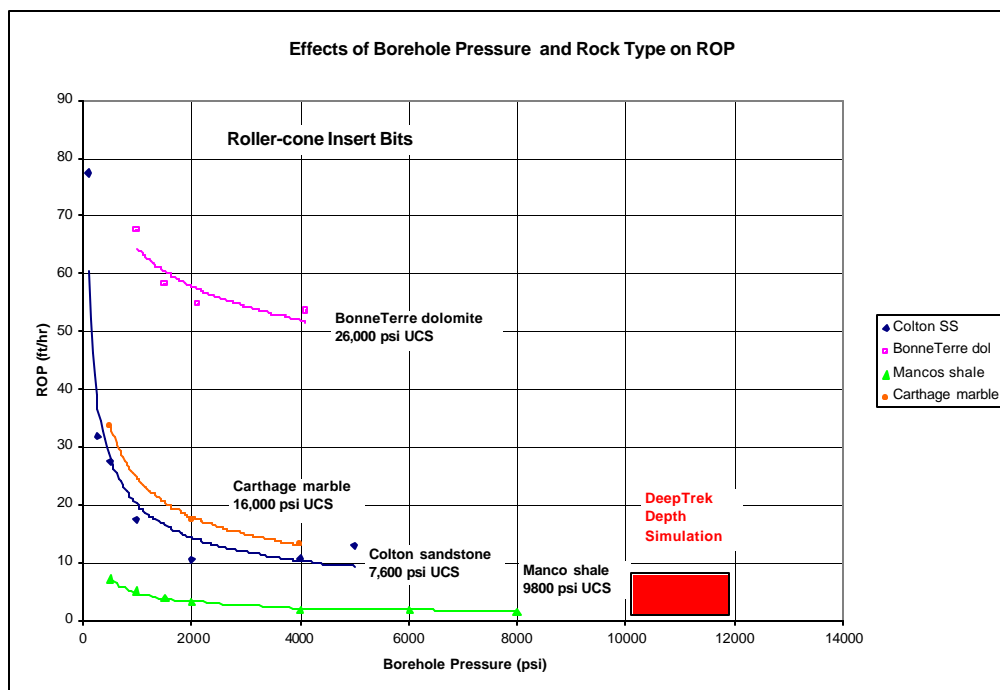
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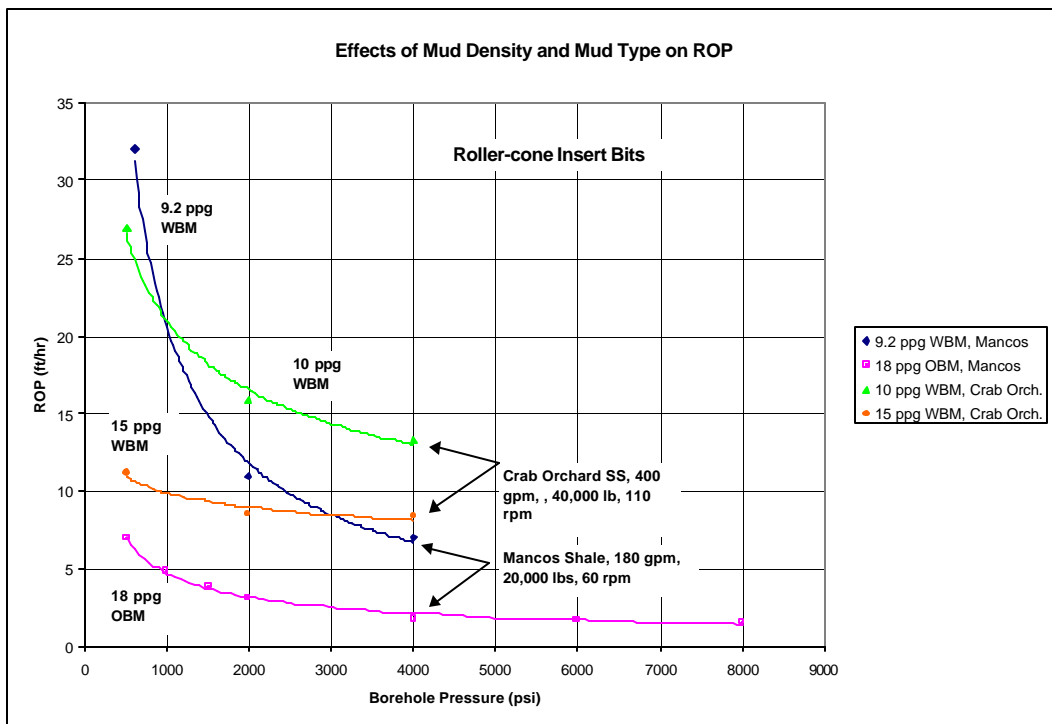
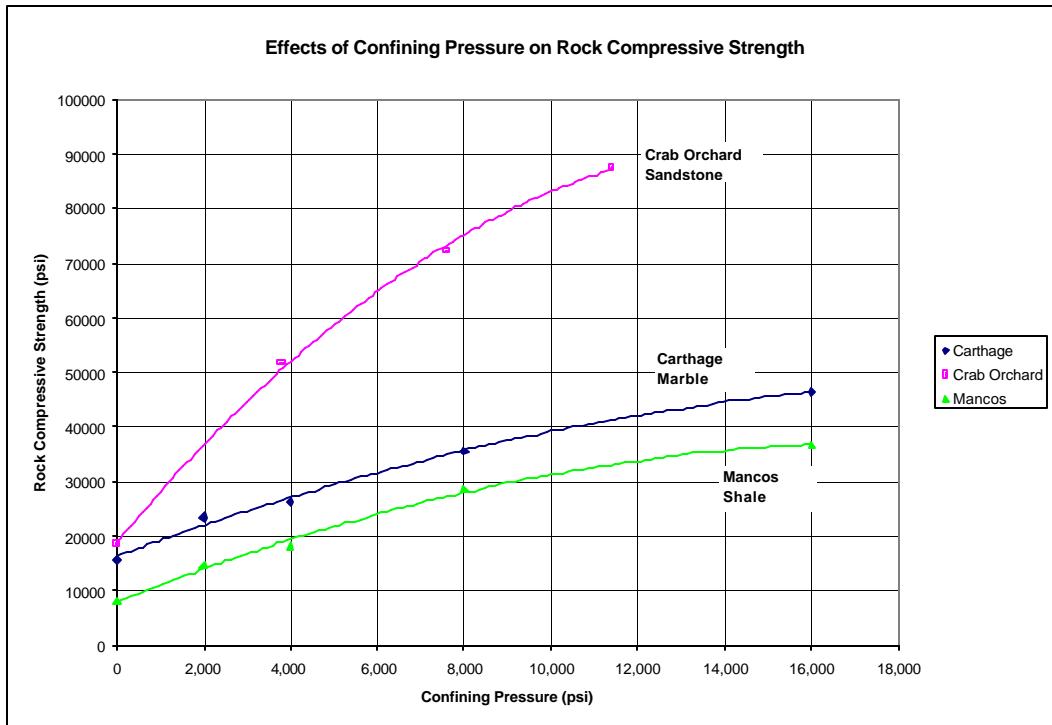
## INTRODUCTION

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.

The focus of the Introduction for this Topical report is on the preparations TerraTek has made for high pressure drilling in the following areas:

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





## EXECUTIVE SUMMARY

### Background

TerraTek will assist in the development and testing of 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. In the field new mud pump developments have increased rig capabilities to 7500 psi and have increased capability to 2200 and 3000 horsepower. 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 is 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.

Last year, accomplishments to date include the following;

#### **4Q 2002**

- Project started
- Industry Team was assembled
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## EXPERIMENTAL

The experimental program determined from discussions with Industry Advisors is covered in detail in the Results and Discussion section (next).

## RESULTS AND DISCUSSION

### Q4 2003

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Industry Advisors planning meeting held November 19, 2003 at Hughes Christensen, The Woodlands, Texas

DeepTrek DOE/Industry Program  
“Optimization of Deep Drilling Performance”  
Meeting 19 November '03  
Executive Summary

### ATTENDEES

At Hughes Christensen offices in The Woodlands;

**Hughes Christensen;** Bob Bennett, Allen Sinor, Rolf Pessier, Brian Miller

**INTEQ Drilling Fluids;** David B. Young, Ron Bland

**National Oilwell;** Bud Trammel, Jerry Johnson

**ConocoPhillips;** Gary Collins

**Marathon;** Jim Mullen, II via telephone link

**TerraTek;** Arnis Judzis, Alan Black

Regrets;

**ARAMCO, ChevronTexaco, BP**

### MEETING OBJECTIVES

The meeting objectives were as follows:

1. Review progress of TerraTek's high pressure drilling facilities
2. Select 'applications' for drilling with 6" range bits for Phase 1
3. Request National Oilwell assistance in pumping services
4. Develop test matrix for Phase 1 program

### SUMMARY

Overview presentation “TerraTek Preparations for High Pressure Drilling Tests” (Alan Black)

Discussion points: INTEQ Fluids asked about temperature capability. Alan Black said that 120 deg F would be the normal maximum. Ron Bland can formulate suitable muds given this requirement. Also 125 bbls of mud would be used for testing. Oil based muds

can be accommodated. Weighting material can be recommended by INTEQ as appropriate for their needs. Finally, the lab facilities will be ready by end February 2004 for start of drilling.

Discussion of “Applications for Deep Drilling Challenges” (A. Judzis, Allen Sinor)

Discussion points: A number of deep gas plays were discussed for ‘representation’ in the DeepTrek project; Tuscaloosa, Arbuckle, Nugget, Mobile Bay, S. Texas, Wyoming, etc. ConocoPhillips and ARAMCO have international rock challenges as well. Rolf Pessier will work with ARAMCO in getting more details about their applications. In the meantime the Industry Team selected the Tuscaloosa and Arbuckle type of applications for the following reasons; they are important deep gas plays domestically, deep drilling performance must be improved, the applications cover different fluid weights – rock types – and drilling fluid design. Hughes Christensen and Baker Hughes INTEQ Drilling Fluids will meet with both BP and Marathon to firm up recommendations for bit and fluids in Phase 1 testing.

Discussion of pumping capacity for high pressure drilling tests (Alan Black, Bud Trammel)

Discussion points: Bud Trammel has located a 1200 hp system. It is reported to be going for \$180,000, however with salvage value it may be possible to use for the program. TerraTek and the DeepTrek project however could not buy it themselves. Bud will review the practicality of such a deal and get back to Alan Black during December. Allen Sinor at Hughes Christensen will also confer with Alan Black.

‘Round table’ discussion of test matrix

*Tuscaloosa type of applications*

Baseline test with oil was discussed

OBM 15.6 or 16 ppg, 22 to 23k feet depth, 5-3/4” bits, 380 to 400 deg F (second mud weight e.g. 12 ppg, maybe one test), also compare to viscosified base oil

Sand (soft to hard), Composite sand/shale (like Mancos) 1 and 2 transitions, Shale

Bit types – impregnated, PDCs, baseline with insert roller cone bit

Flow rates 190-280 gpm

Drilling conditions – rpm, confining, borehole pressure, pressure drop across bit, etc.  
Verify HSI (e.g. like 2)

1. Base oil non-viscosified, PDC 7 bladed, sand-shale composite (one transition)
2. 12 ppg, PDC 7 bladed, sand-shale composite (one transition)
3. 12 ppg, impregnated, sand-shale composite (one transition)
4. 16 ppg, PDC 4 bladed, sand-shale

5. 16 ppg, impregnated, sand-shale
6. 16 ppg, PDC 7 bladed, sand-shale
7. 16 ppg, impregnated, sand-shale-sand (two transitions for balling)
8. 16 ppg, PDC 7 bladed dull, sand-shale
9. 16 ppg, high HSI, PDC 7 bladed, sand-shale
10. Low colloid mud design

Need to consider mud designs per Ron Bland. At least one test low colloid designs for ROP.

*Arbuckle type of application*

Baseline test with water

WBM (11 ppg maybe 12 ppg, 240 deg F) polymer, fresh water dispersed

Dolomite (if limestone maybe Carthage), Sandstone/shale composite sample, Sandstone

Bit types – impregnated, PDC, roller cone baseline

Flow rates

1. Baseline with water, PDC 7 bladed,
2. 11 ppg, impregnated, sand-shale
3. 11 ppg, PDC 7 bladed, sand-shale
4. 11 ppg, roller cone, sand-shale
5. 11 ppg, impregnated, limestone or dolomite?
6. 11 ppg, PDC 7 bladed, limestone
7. 11 ppg, roller cone, limestone
8. Low solid mud design

Discussion ensued about mud types and penetration rates; e.g. low solids dispersed (R Bland). A total of sixteen (16) tests can be accommodated in first phase of the DOE / Industry project.

## **ACTION ITEMS**

1. Hughes Christensen and Baker Hughes INTEQ Drilling Fluids will meet with both BP and Marathon (and possibly others) to firm up recommendations for bit and fluids in Phase 1 testing. The meeting with Marathon has already been scheduled.
2. Bud Trammel at National Oilwell will review pumping options with Alan Black by end December 2003.
3. TerraTek will complete high-pressure upgrades and schedule testing starting end February to March 2004.

Our DOE project manager, William Gwilliam, requested that TerraTek write a paper for the GTI Natural Gas Technologies Conference to be held in Phoenix 9-11 February 2004. TerraTek submitted this paper on time and the manuscript describes the preparations for testing. The paper will be sent electronically to all separately.

I would like to thank Hughes Christensen for hosting this meeting and to all on the Industry Team for their assistance. Once Hughes Christensen and INTEQ conduct their meetings with the operators involved in the Tuscaloosa and Arbuckle type of deep applications, they will be in a position to recommend and provide the best-in-class products for Phase 1 testing.

*Summary by A. Judzis, Executive Vice President TerraTek 3 December '03*

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TerraTek submitted a paper for publication at the upcoming GTI Gas Technologies Conference

## OPTIMIZATION OF DEEP DRILLING PERFORMANCE

Arnis Judzis, Executive Vice President  
Alan D. Black, General Manager Drilling and Completions  
TerraTek, Inc.  
400 Wakara Way  
Salt Lake City, UT 84108

Deep gas drilling at depths in excess of 16,000 feet will improve domestic gas supply in the future. Drilling performance in harder formations, however, drops drastically. Operators often report rates of penetration less than 5 feet per hour. If ROPs could be doubled in domestic hard rock drilling, some estimate savings in excess of \$200 MM per year. A joint DOE and Industry Program is addressing the issues specific to improved diamond bits – drilling fluids for use at depth. Efforts are at an early stage however suppliers and operators on the project team are focusing early development on 5-7/8” and 6-1/8” diamond product bits. Formations and opportunities for success include formations such as Tuscaloosa, Arbuckle, Travis Peak, and Nugget in Wyoming. The paper will report on the set-up and progress for large-scale drilling testing of state-of-the-art bits and drilling fluids at bottomhole pressures in excess of 10,000 psi. Rock types to be drilled may include sandstones, siltstones, and limestones.

**“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”**

## **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 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 manufacturing, and f) commercial experience. The overall objectives are; 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.

The relevance of benchmarking downhole tool performance at high pressures and developing innovative PDC, TSP and 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 in shales at 7,500 psi borehole pressure. This work is a next step in the ability to develop new products for commercialization; the testing will be performed at pressures in the range 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.

## **Context**

The work addresses improvements in deep well drilling performance through rigorous proof-of-concept testing of new drilling components at high borehole pressures, 10,000 to 12,000 psi. (22,000 to 26,000 feet simulated depth). Specifically the work focuses on the development of new and innovative diamond product drill bit technologies and advances in high pressure-high temperature fluids for various deep, slow drilling applications. In the past operators such as BP America have articulated the need for deep drilling performance improvements for such areas as Tuscaloosa trend, Western Oklahoma, and Anadarko Basin and looking ahead to some deep gas exploration plays, challenges include rates of penetration (ROP), hydraulics limitations at great depth, and dynamics –

problems such as ‘slip-stick’. This program is a phased approach to developing and commercializing a ‘*smart drilling bit-fluid system*’ combining the features of new impregnated and advanced PDC bit technologies and fluids specifically benchmarked and proven for high pressure applications. Other operators and suppliers expressed similar concerns at the DOE Deep Trek Workshop in March 2001. There some of the significant ROP problems were addressed; ie. rock strength can be high and variable, there is a lack of aggressive drag bits, persistent low ROPs are viewed as serious non-productive time, ROP increases can justify development costs of new downhole tools, rock variability often requires ‘smarter bits’ capable of drilling with a consistently higher ROP, and bit vibration can induce failures.

### Technical Approach

TerraTek and the industry team will 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 will benchmark performance and provide bit developments first for a 6” diameter range. John Shaughnessy, BP’s Senior Drilling Engineering for the Tuscaloosa trend, noted at the March 2001 Department of Energy DeepTrek Workshop in Houston 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”.

### Assurance process

The operational nature of this deep drilling performance project will allow more technology transfer in the following additional ways:

Industry Advisory Group – The original industry group included Hughes Christensen, Baker Hughes INTEQ Drilling Fluids, and National Oilwell to work closely with TerraTek, BP, ExxonMobil, ConocoPhillips, and Marathon. Aramco has also joined the advisory team since late 2002.

Peer Assist – Technology can be transferred to / from operator clients via a peer assist function managed by the Project Manager. The usefulness of peer assists was exemplified by BP Exploration in a recent publication detailing improved technology transfer among operating business units and suppliers of drilling equipment and services. After Judzis<sup>1</sup>, “It is a tool which promotes learning among groups . . . .”.

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<sup>1</sup> Judzis, A., Stoltz, D.A., and Wolfson, L., “Managing Peer Assists – Case Study of Improved Extended Reach Drilling Performance”, SPE/IADC Paper Number 52775 presented at the 1999 SPE/IADC Drilling Conference held in Amsterdam, Holland 9-11 March 1999.

At the project's kick-off meeting end 2002, BP Exploration and Baker Hughes INTEQ outlined industry challenges and perspectives. **The 'Domestic Business Challenge; Tuscaloosa' example was presented by BP Exploration's Richard H. Reiley at DOE Morgantown December 17, 2002 (R. Reiley is no longer with BP)**

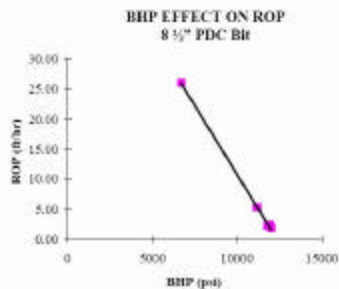
### Deep Hard Rock Drilling Challenge



- 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



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**

### 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?**

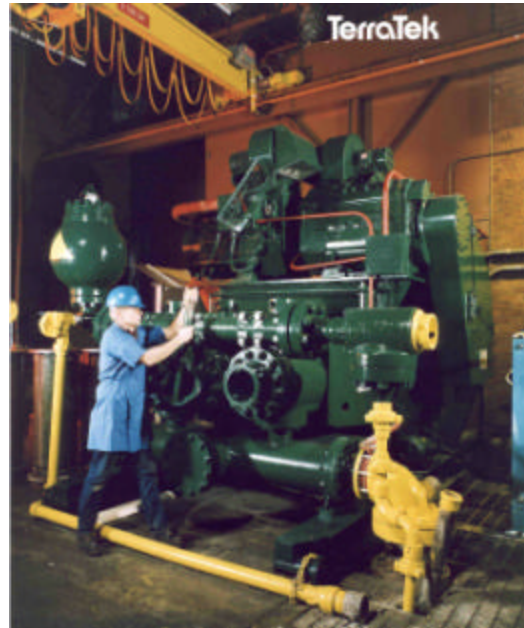
## Facilities

TerraTek's Drilling and Completions Laboratory Division provides facilities for large-scale drilling and completions research and testing at simulated downhole conditions, and modeling software for hydraulic fracturing design. The Drilling Laboratory's facilities include a wellbore simulator pressure vessel, a full-scale drill rig and mud pumping capabilities for measuring the performance, wear, deviation and dynamics of full size drill bits tested at overbalanced or underbalanced drilling conditions at simulated depth. Existing facilities can perform the following tests:

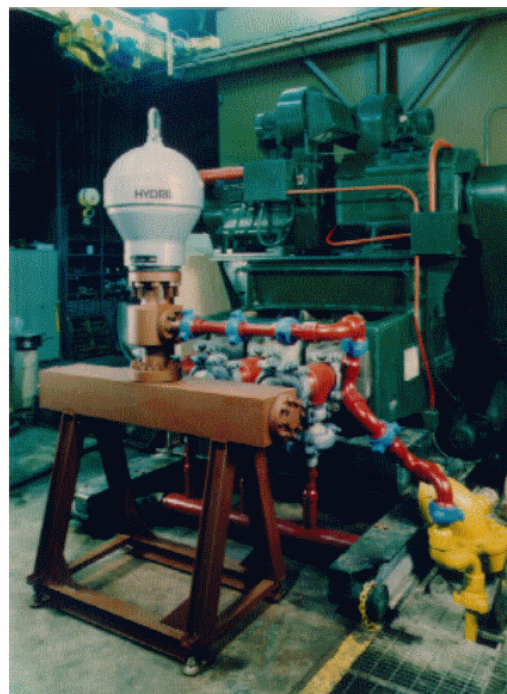
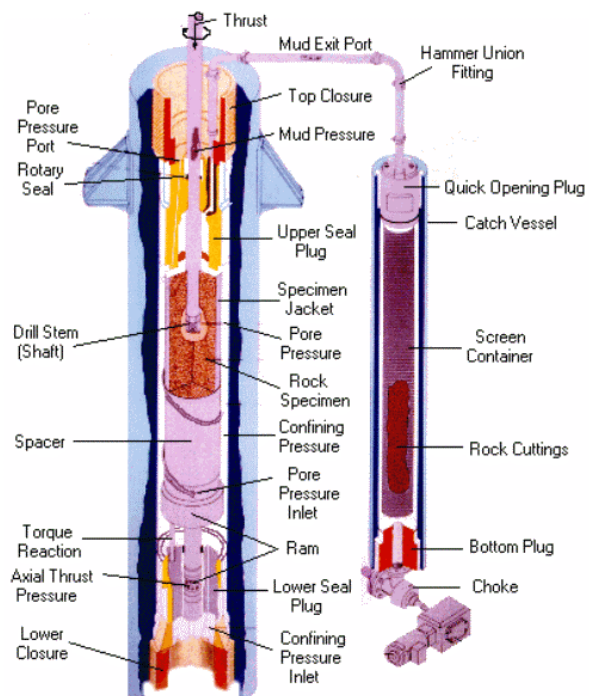
- Full-size bit performance evaluations, including measurement of rate of penetration, torque and mechanical horse-power.
- Overbalanced and underbalanced drilling performance measurements, including measurement of rate of penetration and formation damage.
- Drilling performance and bit balling determinations in shale, as functions of the drilling fluid, simulated depth, bit type and drilling conditions.
- PDC bit wear testing in abrasive and fractured rocks.
- Full-size coring performance and core damage testing, measuring the effects of core bit design, coring fluid and coring conditions on core invasion.
- Novel bit testing, including high-pressure jet cutting, improved nozzle design and hydraulics, and unconventional cutting structures.
- Percussion hammer testing, including air, mud or clear fluid hammers.
- Bit deviation and walking tendencies, measured while drilling into formations with different bedding plane orientations, at simulated depth.
- Vibration and dynamic bit performance measurements, made with near bit weight-on-bit, torque, bending, and accelerometer sensors.



Drilling Rig



Mud Pump  
High Pressure Fluid Ends (below)



## Progress

The set up for the high pressure drilling tests for the DOE Deep Trek project involves upgrades to existing equipment and capabilities at TerraTek including: upgrading safety equipment; increasing the pumping capacity and mud handling capacity of two pumping systems; increasing the ability to generate high borehole pressures by choking the flow and cooling the mud; upgrading the ability to handle pump pulsations and seal high pressures at the pump fluid ends, rotary shaft and swivel; and preparation of drilling samples and drilling fluids for 16 tests in both the first and second phases and 8 tests for the third phase. A brief breakdown for each category is given below:

1. **Rocks and Rock Preparation:** Rocks supplied will be 15 ½" diameter by 36" long samples of various hard sandstones, siltstones, limestones and potentially other hard rock. Materials include the rock cores, sample jackets for high confining pressures, expendable diamond cores barrels and saw blades for the harder rocks.
2. **Drilling Mud Materials, Mixing Equipment and Disposal:** Because of the amount of shearing and heat build-up in the drilling mud, larger than normal batches of mud will be prepared for the high pressure drilling tests. For example, mud batches of 100-150 barrels will be needed compared with standard 50-barrel mixes. Mud materials, upgrade of mud mixing capabilities and mud disposal are needed.
3. **High Pressure Piping, Fittings, Chokes and Mud Cooling:** The high borehole pressures (up to 12,000 psi) will be created by choking the flow. This cannot be done by a single choke, but will require a series of three fixed bean and two variable chokes. Associated with high pressure choking of abrasive drilling fluid is protection of downstream piping from cavitation and erosion and also the ability to cool the drilling mud to maintain relatively constant mud temperatures. High pressure cuttings collection vessel, high pressure piping, Chiksan high pressure swivel fittings, fixed bean chokes and housings, variable choke, downstream piping protection, expansion of an existing heat exchanger and associated mounting brackets, fixtures, etc. are being upgraded.
4. **High Pressure Pulsation Dampening and Sealing Mud at Pump Fluid Ends, Rotary Shaft and Swivel:** Pumping mud at high pressures will result in large pulsations and wear and tear on pump seals, valves and valve seats as well as high pressure seals for sealing the drill shaft and swivel. A high-pressure pulsation dampener, expendable seals, seal backups, valves seats, valves, etc. will be needed.
5. **High Pressure Pumping Capacity With Rental Pumping Capacity:** The current high pressure capabilities at TerraTek includes the high pressure fluid ends which has the capacity of 15,000 psi at 180 gpm flow. Additional flow capacity of about 110 gpm to give a total of 290 gpm will be needed. Supply of an additional pump from National Oilwell, rental or purchase of the pump driver, unitization of the pump and

pump driver and piping and fittings to tie the pump into the TerraTek system are needed.

6. Safety Upgrades for Handling High Pressure Equipment and Operations: It is a high priority to carry out the high pressure drilling tests in the program safely. Upgrades include expendables to refurbish pressure relief valves, setting a remote monitoring system with cameras, monitors, etc, setting up a communication system to coordinate the operation of the two pumping systems and other operations during the test and remote operation of all equipment.

The following upgrades are either in progress or have been completed in order to commence full scale high pressure drilling tests end 2003.

#### Rock Preparation:

-Thicker jackets	Received
-Machine o-rings in end caps	Completed
-Improved jacket sealing and clamping	Completed



#### Drilling Fluid Cooling:

-Expanded heat exchanger	Completed
-Set up large tank for 125 bbls of mud	Completed
-Pit jetting in corners	Completed
-Rapid pressurization of vessel	Completed

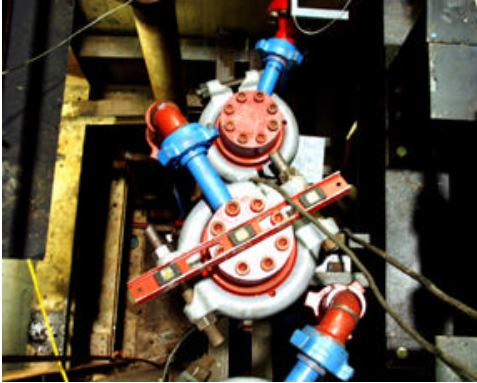


### High Pressure Mud Choking:

- Multiple fixed bean choke manifold and variable choke
- Down stream piping protection
- High pressure cutting collection vessel
- High pressure piping
- High pressure Chiksan fittings

Fixed chokes received  
Choke holders received  
And assembled  
Parts complete and  
assembly complete  
Completed  
Received and assembled  
Received and assembled





#### High Pressure Mud Sealing and Pulsation Dampening:

-Rotary seals and backups	Completed, need backups
-Swivel seals and backups	Completed, need backups
-Mud pump seals and backups	Completed, need backups
-Pulsation dampening Hydril experimental dampener	In house
-Pulsation dampening rental	Will address after first test

#### High Pressure Mud Pumping Capacity:

-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

#### Safety and Operational Features:

-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	Completed



### Testing Considerations

- Bit size 5-7/8 and 6-1/8”/Rock size
- Rock Types – sandstone, siltstone, limestone
- 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



Cuttings screen

## Engineering Meeting (1Q 2003) - Industry Input

During the start of this project, operators have supplied some 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 a test matrix. Most ensuing discussion covered pumping requirements and testing of 6" vs. 8-1/2" range bits. Consensus developed towards testing bit sizes of 5-7/8" and 6-1/8", thus DeepTrek Phase 1 objectives will be met with the development and testing of the nominal 6" sizes (5-7/8" and 6-1/8") over a range of flow rates. Baseline bit performance was also discussed, opening up the possibility of running a roller cone bit or other.

Rock types and stress conditions – Operators have provided 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.

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 – impregnated diamond, PDC, TSP, perhaps natural diamond, baseline rollercone?
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.

### Phase 1 Proposed Test Matrix (to be updated end November 2003)

<b>TEST MATRIX-DEEP DRILLING PROGRAM</b>				
<b>TEST NUMBER</b>	<b>BIT</b>	<b>ROCK SAMPLE</b>	<b>MUD TYPE</b>	<b>TEST OBJECTIVE</b>
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

				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				

## Conclusions

1. High pressure readiness and preparation has taken 4 months longer than scheduled. However the capabilities to accommodate drilling at such pressures with full scale bits are nearly complete. This is unique to the industry.
2. Industry input to date has been very good. The suppliers of diamond product drill bits (Hughes Christensen) and drilling fluids (INTEQ Drilling fluids) are keen to contribute to this important development and testing program.
3. Phase 1 drilling program will commence end 2003 or early 2004.

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## Q1 2004

TerraTek presented a paper entitled "Optimization of Deep Drilling Performance" at the GTI Natural Gas Technologies Conference held 8-11 February 2004 in Phoenix, Arizona at the request of DOE.

## Q2 2004

### Industry input on one 'application' for DeepTrek simulation

To: "Alan Black", INTERNET:ablack@terratek.com  
To: "Arnis Judzis", ArnisJudzis  
From: "Sinor, Allen", INTERNET:Allen.Sinor@hugheschris.com  
Date: 5/25/2004, 2:16 PM  
Re: FW: Fox 9 lithologies

Allen Sinor  
Manager- Drilling Research  
Hughes Christensen Co.  
281-363-6460 office

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

From: Roy, Bryan J. [mailto:BJRoy@MarathonOil.com]  
Sent: Tuesday, January 27, 2004 11:17 AM  
To: Sinor, Allen  
Subject: FW: Fox 9 lithologies

Allen

This is the only one that I had in my folder. If there's another one, let me know and I can have a few folks chase it.

Bryan

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

From: Knowles, Steven P.  
Sent: Saturday, December 06, 2003 11:35 AM  
To: Mullen, II, Jim  
Cc: Roy, Bryan J.  
Subject: Fox 9 lithologies

Attached is an Excel spreadsheet with more detailed lithology description from the Viola to TD.

I will forward the penetration rate data for the Fox 9 when the network is back up on Monday.

Steve

<b>Depth</b>		<b>Lithology of Fox Alliance #9-3, Section 3, T2N-R5W, Stephens Co., OK</b>
<b>From</b>	<b>To</b>	
13684	13730	90% fine to medium grained limestone; 10% chert
13730	14340	99% fine grained limestone; 1% chert
14340	14370	70% microcrystalline to fine grained limestone; 30% chert
14370	14410	fine grained limestone
14410	14440	70% fine grained limestone; 30% lt gy shale
14440	14670	fine grained limestone
14670	14750	50% shale; 30% siltstone; 20% sandstone
14750	14838	fine to medium grained sandstone
14838	14954	50% shale; 40% siltstone; 10% sandstone
14954	15290	fine to medium grained sandstone
15290	15304	shale, waxy
15304	15390	fine to medium grained sandstone
15390	15415	shale, waxy
15415	15560	60% siltstone; 30% shale; 10% sandstone
15560	15640	very fine to fine-grained sandstone
15640	15790	60% siltstone; 30% shale; 10% sandstone (repeat of 15475 - 15560)
15790	15880	very fine to fine-grained sandstone (repeat of 15560 - 15640)
15880	16518	45% shale, fine to waxy; 35% limestone; 20% siltstone
16518	16650	very fine grained sandstone
16650	16760	very fine to medium grained sandstone
16760	16930	very fine to medium grained limestone
16930	17020	70% dolomite; 30% anhydrite (where density porosity < -6%)
17020	17150	microcrystalline to fine grained limestone
17150	17690	50% limestone; 30% dolomite; 20% anhydrite
17690	17930	microcrystalline to fine grained limestone
17930	18025	50% medium grained dolomite; 50% fine to course grained limestone
18025	18110	fine grained limestone
18110	18320	medium grained dolomite
18320	18530	fine grained limestone
18530	18710	medium grained dolomite
18710	18760	fine grained limestone

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Engineering and planning meeting was held at Hughes Christensen May 25, 2004 to develop a test matrix after the early input by Industry Advisors on deep drilling applications and possible simulated downhole conditions

DeepTrek DOE/Industry Program  
“Optimization of Deep Drilling Performance”

Meeting 25 May '04

Summary

**ATTENDEES**

At Hughes Christensen offices in The Woodlands;

**Hughes Christensen;** Allen Sinor, Rolf Pessier

**INTEQ Drilling Fluids;** Ron Bland

**TerraTek;** Arnis Judzis, Alan Black (Alan Black via teleconference)

**MEETING OBJECTIVES**

The meeting objectives were as follows:

1. Review test matrix for DeepTrek
2. Set drilling pre-planning meeting date for summer 2004

**SUMMARY**

Discussion of test matrix

*Tuscaloosa type of applications (BP, etc.)*

Drilling fluids – Diesel or mineral base oil (per Ron Bland), 12 ppg, and 16 ppg (standardize solids content with 45 ppb rev dust in the low weight muds and 30 ppb in the 16 ppg OMB/MOBM). Note – 120 bbl needed, build 12 and 16 ppg from same base oil.

Diamond product drill bits – Impregnated, PDC 7 bladed, PDC 7 bladed ‘dull’, PDC 4 bladed (5-3/4 or 5-7/8”)

Rock types – Rolf Pessier to supply additional data; tentative Mancos shale and Crab Orchard sandstone.

Flow rates – aim for ~300 gpm

Drilling conditions – rpm (90 for PDC and 60/90/120/240 for impreg), confining (13,000 psi), borehole pressure (11,000 psi), bit pressure drop <2,000 psi.

11. Base oil non-viscosified, PDC 7 bladed, sand-shale composite (sand on top)
12. 12 ppg, PDC 7 bladed, sand-shale composite
13. 12 ppg, impregnated, sand-shale composite
14. 16 ppg, PDC 7 bladed, sand-shale composite
15. 16 ppg, PDC 4 bladed, sand-shale composite
16. 16 ppg, impregnated, sand-shale
17. 16 ppg, PDC 7 bladed, field dull, sand-shale composite
18. 16 ppg, high HSI (> 2 HSI), PDC 7 bladed, sand-shale composite
19. Low colloid mud design

*Arbuckle type of application (Marathon, etc.)*

Drilling fluids – water, 11 ppg (standardize solids content with 45 ppb rev dust)

Diamond product drill bits – Impregnated, PDC 7 bladed, roller cone (5-3/4 or 5-7/8")

Rock types – Rolf Pessier to supply additional data; tentative Carthage marble and Crab Orchard sandstone.

Flow rates – aim for ~300 gpm

Drilling conditions – rpm (90 for PDC, 60/90/120/240 for impreg, 70-80 for roller cone), confining (13,000 psi), borehole pressure (11,000 psi) bit pressure drop <2,000 psi.

9. Baseline with water, PDC 7 bladed, sandstone-limestone composite (sand on top)
10. 11 ppg, PDC 7 bladed, sandstone
11. 11 ppg, impregnated, sandstone
12. 11 ppg, roller cone, sandstone
13. 11 ppg, PDC 7 bladed, limestone
14. 11 ppg, impregnated, limestone
15. 11 ppg, roller cone, limestone

#### Next meeting

TerraTek will host a meeting for the DeepTrek drilling program in Salt Lake City July 13, 2004. The DOE and all interested industry advisors will be invited. The drilling program will commence beginning August 2004.

*Summary by A. Judzis, Executive Vice President TerraTek 21 June '04*

**Q3 2004**

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Industry Advisor input

To: "Arnis Judzis", ArnisJudzis  
From: "Caicedo, Hector", INTERNET:CAICEHU@chevrontexaco.com  
Date: 7/7/2004, 6:43 AM  
Re: RE: DeepTrek Project Planning Meeting

Arnis,

Thank you for the information and invitation but, unfortunately I can not attend the meeting this time due to other commitments and projects I am working now.

I could do the ROP predictions for all bit types selected if you could provide me some data.

- Bit type (e.g. pdc bit with 6 blades and 13 mm cutters)
- Rock type
- Rock strength, UCS and CCS, confining pressure
- Mud weight
- Drilling parameters (RPM, WOB)
- Pore pressure if different than normal pressure or atmospheric pressure.

I'll try to attend your next meeting when testing bits.

Thank you and regards,

Hector

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

From: Arnis Judzis [mailto:ArnisJudzis@compuserve.com]  
Sent: Friday, July 02, 2004 2:09 PM  
To: Tim Grant; Jim C Mullen; Gary J Collins; Sweep, Miles (mnsu); Caicedo, Hector; Richard R Harting; James Rigby; Jesse Holster; Tim Travis; Nigel C Last; Ken Armagost; Kent Corser; Ron Bland; Allen Sinor; Rolf C Pessier; David B Young  
Cc: Alan Black; William Gwilliam; Arnis Judzis  
Subject: DeepTrek Project Planning Meeting

Gentlemen,

This is confirmation of the DOE DeepTrek project meeting

to be held Tuesday morning July 13, 2004. I have forwarded the test matrix we plan to discuss and have talked to many of the Industry Advisors directly. Owing to vacations, some will not be able to make it, however we need to finalize operational considerations before start of drilling in August.

Venue; TerraTek, 400 Wakara Way, Salt Lake City 84108 switchboard phone (801) 584-2400

Time; 8:30 - noon This allows participants to return to Houston on Continental Airlines on the afternoon flight.

Agenda;

8:30 Introductions and confirmation of test matrix  
9:00 Finalization of bits and mud programs by Hughes Christensen and B-H INTEQ Drilling Fluids, respectively 10:00 Pump and high pressure fluid end issues 11:00 Scheduling and budget issues 12:00 tour of facilities / Adjourn Lunch - those staying

If Hector Caicedo from ChevronTexaco can attend we may get into a discussion of ROP prediction and performance data!

Please let me know who will be attending.

For your information, the DOE has assigned a new project manager to our group. He is Tim Grant and is officed in Pittsburgh. Unfortunately he cannot make this job pre-planning meeting, however he has received some briefing information from William Gwilliam. We welcome him!

Regards,

Arnis Judzis  
TerraTek  
judzis@terratek.com  
(801) 584-2483

-----Forwarded Message-----

From: Arnis Judzis, INTERNET:ArnisJudzis@compuserve.com  
To: Ken Armagost, INTERNET:armagokw@bp.com  
Nigel C Last, INTERNET:lastnc@bp.com  
Kent Corser, INTERNET:corserk@bp.com  
Rolf C Pessier, INTERNET:rolf.pessier@hugheschris.com  
Allen Sinor, INTERNET:Allen.Sinor@hugheschris.com

David B Young, INTERNET:david.young@inteq.com  
Ron Bland, INTERNET:ron.bland@inteq.com  
Gary J Collins, INTERNET:Gary.J.Collins@conoco.com  
Jim C Mullen, INTERNET:jcmullen@marathonoil.com  
Hector U Caicedo, INTERNET:caicehu@chevrontexaco.com  
Miles N Sweep, INTERNET:mnsu@chevrontexaco.com  
Richard R Harting, INTERNET:richard.harting@aramco.com  
Jesse Holster, INTERNET:jesse.holster@exxonmobil.com  
Tim Travis, INTERNET:tim.travis@exxonmobil.com  
Alan Black, INTERNET:ablack@terratek.com  
William Gwilliam, INTERNET:william.gwilliam@netl.doe.gov

CC: Arnis Judzis, INTERNET:judzis@terratek.com

Date: 6/21/2004 11:36 AM

RE: DeepTrek High Pressure Drilling Program JIP

Gentlemen,

Attached please find a refined test matrix for the 'Optimization of Deep Drilling' program scheduled for August 2004. After a long period of preparations we are finally ready to conduct performance testing at simulated depth conditions previously not achieved in laboratory environments. We are grateful for the assistance by Hughes Christensen (diamond product bits and development) and Baker Hughes Inteq Drilling Fluids. The industry advisors are keen to look at both fluids and state-of-the-art bits as we benchmark and acquire performance data suitable for a next phase of development.

Please note that TerraTek will host a job pre-planning meeting 13 July 2004. All are encouraged to attend. I realize that some personnel changes have occurred with many companies, however the enthusiastic DeepTrek presentation originally done by BP's John Shaughnessy set a clear vision for drilling performance at depth.

Regards,

Arnis Judzis, Executive Vice President  
TerraTek  
judzis@terratek.com  
+1 (801) 584-2483

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Request by Robert Radtke to include his TSP bit in DeepTrek project

To: "Tim Grant", INTERNET:Tim.Grant@NETL.DOE.GOV  
To: "William Gwilliam", INTERNET:WILLIAM.GWILLIAM@NETL.DOE.GOV  
CC: Amis Judzis, INTERNET:judzis@terratek.com  
From: Robert Radtke, INTERNET:radtke@kingwoodcable.com  
Date: 7/20/2004, 10:16 AM  
Re: RE: Bill,

Gentlemen: TII has prepared a 8-12 inch diameter drill bit with thermally stable diamonds cutters for testing at Terra Tek. I will contact Arnis to set up the schedule.

Sincerely,

Bob Radtke  
Technology International, Inc.  
2103 River Falls Drive  
Kingwood, Texas 77339-3154  
(281) 359-8520  
(281) 359-8527 (fax)

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

From: William Gwilliam [mailto:WILLIAM.GWILLIAM@NETL.DOE.GOV]  
Sent: Tuesday, July 20, 2004 9:06 AM  
To: radtke@kingwoodcable.com; Tim Grant  
Subject: Re: Bill,

Tim, (and Bob Radtke)

As far as I know Technology International is planning on doing some tests with their own funding (combined DOE/NETL and Phase III cost-share from TI) at Terra Tek. I will cc this message to Bob Radtke for his response to you and I both. I am not certain on the expected timing of the next tests for Bob's TSP bits and perhaps he can give us an update. To answer your question, I believe there is value in gathering additional data at Terra Tek with Bob's TSP cutter bits.

Bill Gwilliam

William J. Gwilliam  
Senior Geologist/Project Manager  
National Energy Technology Laboratory  
U.S. Department of Energy  
3610 Collins Ferry Rd. (P.O. Box 880)

Morgantown, WV 26505, USA  
Phone: (304) 285-4401  
Fax: (304) 285-4403  
e-mail: william.gwilliam@netl.doe.gov

>>> Tim Grant 7/20/2004 9:17:27 AM >>>  
Bill,

I've spoken with Arnis Judzis a few times. He mentioned your interest in having the TSP bit tested. Is this something worth doing and finding the funds needed for the test? Terra Tek tentatively plans to start Phase I testing the last week of August or first week of September.

Tim

\*\*

Hughes Christensen still committed to providing added pumping capacity

To: Alan Black, INTERNET:ablack@terratek.com  
To: Rolf C Pessier, INTERNET:rolf.pessier@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: Kent Corser, INTERNET:corserk@bp.com  
To: Ken Armagost, INTERNET:armagokw@bp.com  
To: Nigel C Last, INTERNET:lastnc@bp.com  
To: James Rigby, INTERNET:james.rigby@exxonmobil.com  
To: Jesse Holster, INTERNET:jesse.holster@exxonmobil.com  
To: Tim Travis, INTERNET:tim.travis@exxonmobil.com  
To: Richard R Harting, INTERNET:richard.harting@aramco.com  
To: Hector U Caicedo, INTERNET:caicehu@chevrontexaco.com  
To: Miles N Sweep, INTERNET:mns@chevrontexaco.com  
To: Gary J Collins, INTERNET:gary.j.collins@conocophillips.com  
To: Jim C Mullen, INTERNET:jcmullen@marathonoil.com  
To: Tim Grant, INTERNET:tim.grant@netl.doe.gov  
CC: Arnis Judzis, INTERNET:judzis@terratek.com  
From: Arnis Judzis, INTERNET:ArnisJudzis@compuserve.com  
Date: 7/21/2004, 10:47 AM  
Re: DeepTrek Meeting Summary and Mud Pump Detail

DeepTrek Team:

We met with Hughes Christensen in Houston last week owing to vacation and other scheduling difficulties for some operators to come to Salt Lake City.

Allen Sinor (Hughes) and Alan Black (TerraTek) made progress in coordinating our schedules for the upcoming DeepTrek drilling tests under the project entitled "Optimization of Deep Drilling Performance".

Attached are two files -

1. Anticipated timetable for 1300 hp mud pump
2. Test matrix for two selected US fielded applications (you have seen this before)

The notable change in the schedule is start of drilling to the week of August 23. This is due to the delay in receiving the diesel engine. In the meantime Allan and Alan will coordinate crews and logistics such as fuel, crane, etc.

We will start drilling during the week of August 23 or 30 and invite interested parties to witness the tests and discuss the results. I am not yet setting any specific meeting date - some operators prefer to come up and review information sometime after drilling starts. We anticipate the schedule to last 3 weeks or longer.

The first series of tests will deal with the 'Arbuckle' type of application and will use water based muds. Jim Mullen at Marathon has been in frequent contact with Hughes Christensen on some of the program details during the first half of 2004. Additionally for your information, Rolf Pessier will have details about the 6" bits - impreg, PDC, etc. should you require advance notice. ChevronTexaco's Hector Caicedo has offered to perform some ROP prediction calculations also.

The second series of tests will be for the 'Tuscaloosa' type of application and will use an oil based mud. Ron Bland at Inteq Drilling fluids will soon have the details of that formulation.

Again many thanks for your patience. I'll leave it to Alan Black and the great staff at Hughes and Inteq to work out the details over the next three weeks. As time gets close to drilling I will contact many of you individually about plans to review performance data and witness testing. Testing at these conditions has not been done to date and should be rather interesting.

I also plan to give an update on this program to the Drilling Engineering Association / IADC at their 3Q 2004 meeting on August 19, 2004 in Houston.

Best regards,

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

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Updated Industry Advisor test matrix

To: Ron Bland, INTERNET:ron.bland@inteq.com  
To: Allen Sinor, INTERNET:allen.sinor@hugheschris.com  
CC: Arnis Judzis, INTERNET:judzis@terratek.com  
From: Alan Black, INTERNET:ablack@terratek.com  
Date: 7/28/2004, 3:01 PM  
Re: DeepTrek Planning

Allen/Ron,

We are starting to put together a test plan and procedures for carrying out the DeepTrek testing and have prepared the attached test matrix. There are several question marks that we will need your help filling in i.e. size and description of the bits, nozzles sizes, range of WOB's and the drilling fluid formulations. We have 300 gpm as the flow rate which is the maximum previously suggested (240-300 gpm was suggested by Rolf). Do we want to stay with the 300 gpm for all the tests and size the nozzles to get the 2 HSI and 5 HSI (for Test DT13) or have a lower GPM for all the tests except Test DT13 with would have the 300 gpm? You will know best what is appropriate for a 6" range bit size.

Also, Test DT16 is not defined. At one time, another drilling fluid type was suggested or we could leave it open for another test with the 16 ppg OB. Once we have this information set, then we will put together some procedures and detailed test conditions, drilling distances, etc. for each test for review. Thanks.

Alan Black  
TerraTek, Inc.  
400 Wakara Way  
Salt Lake City, Utah 84108  
801-584-2441 phone  
801-584-2406 fax  
ablack@terratek.com e-mail

Test Matrix for DeepTrek Phase 1 Updated: July 28, 2004												
PDC 7-Blade Description: ?												
PDC 4-Blade Description: ?												
Roller Cone Description: ?												
Impregnated Description: ?												
Rock Description: CO/Carth & CO/Mancos-17"/19" Long w/14" Drilling Distance Each; CO and Carthage 36" Long w/30" Drilling Distance Each												
Arbuckle Test Series with 11 ppg Water-base Fluid and Crab Orchard and Carthage Marble Samples												
Test #	Bit	Rock	Mud	Flow Rate	Nozzles	HSI	Borehole	Confining	Overburd.	Ram	RPM	WOB
DT1	PDC 7-Blade	CO/Carth	Water	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT2	PDC 7-Blade	Carth	11 ppg WB	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT3	PDC 7-Blade	CO	11 ppg WB	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT4	Roller-cone	Carth	11 ppg WB	300	?	2 HSI	11,000	12,000	13,000	14,000	70-80	?
DT5	Roller-cone	CO	11 ppg WB	300	?	2 HSI	11,000	12,000	13,000	14,000	70-80	?
DT6	Impregnated	Carth	11 ppg WB	300	?	2 HSI	11,000	12,000	13,000	14,000	60-250	?
DT7	Impregnated	CO	11 ppg WB	300	?	2 HSI	11,000	12,000	13,000	14,000	60-250	?
Tuscaloosa Test Series with 16 ppg Oil-base Fluid and Crab Orchard and Mancos Shale Samples												
Test #	Bit	Rock	Mud	Flow Rate	Nozzles	HSI	Borehole	Confining	Overburd.	Ram	RPM	WOB
DT8	PDC 7-Blade	CO/Mancos	Base Oil	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT9	PDC 7-Blade	CO/Mancos	12 ppg OB	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT10	Impregnated	CO/Mancos	12 ppg OB	300	?	2 HSI	11,000	12,000	13,000	14,000	60-250	?
DT11	Impregnated	CO/Mancos	16 ppg OB	300	?	2 HSI	11,000	12,000	13,000	14,000	60-250	?
DT12	PDC 7-Blade	CO/Mancos	16 ppg OB	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT13	PDC 7-Blade	CO/Mancos	16 ppg OB	300	?	5 HSI	11,000	12,000	13,000	14,000	90	?
DT14	PDC 7-Dull	CO/Mancos	16 ppg OB	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT15	PDC 4-Blade	CO/Mancos	16 ppg OB	300	?	2 HSI	11,000	12,000	13,000	14,000	90	?
DT16	TBD	CO/Mancos	TBD	300	?	2 HSI	11,000	12,000	13,000	14,000	?	?
11 ppg WB Mud Formulation					12 ppg OB Mud Formulation				16 ppg OB Fluid Formulation			
RexDust			45 ppb		RexDust			45 ppb	RexDust			30 ppb

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An update of the DeepTrek project was made to the 3Q 2004 meeting of the Drilling Engineering Association



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

### ***DeepTrek; Optimization of Deep Drilling Performance***

Arnis Judzis, Executive Vice President  
Drilling Engineering Association Meeting  
August 19, 2004



### **DOE DeepTrek 'Optimization of Deep Drilling Performance'**

- DEA 148 Diamond Bit development project part of project
- \$ 3 million project on diamond product bit and smart fluid development for deep drilling applications (>16,000 ft TVD)
- Service company partners B-H Inteq & Hughes Christensen
- Advisory Board open for more operator input
- Will drill in TerraTek's Wellbore Simulator
  - Pressures** > 11,000 psi wellbore
  - 6" range various bits** – PDC, impregnated, baseline roller cone
  - Rock types** – Crab Orchard sandstone, Carthage marble, Mancos shale
  - Drilling fluids** – various
- Scope of Work
  - Benchmark performance of emerging products
  - Develop and test new aggressive bits and 'smart' drilling fluids
  - Conduct field tests of the prototype developments (bits, fluids)

## Example Domestic Business Challenge

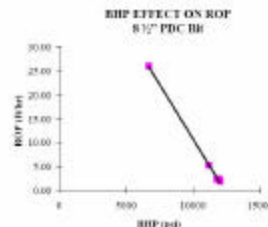
### Deep Hard Rock Drilling Challenge

- 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.**

Per Rich H. Reiley,  
Formerly BP America

### Deep Hard Rock Drilling Challenge



## Development of Test Matrix for High Pressure Drilling (Industry Team)

### *Tuscaloosa type (e.g. BP America, etc.)*

- OBM ~16 ppg, 22-23 k ft TVD, 5-3/4" bits, 380 deg F
- Sand (soft to hard), shale
- Testing
  - Bits; PDC, impregnated diamond, baseline
  - Fluids; OBM, baselines w/mineral oil, novel design
  - Rock samples; shale-sand composites
- Drilling parameters
  - RPM, confining pressure, borehole pressure, pressure drop across bit, WOB, hydraulics

## Development of Test Matrix for High Pressure Drilling (Industry Team)

### *Arbuckle type (e.g. Marathon, etc.)*

- WBM ~12 ppg, > 15 k ft TVD, 6" range bits, 240 deg F
- Dolomite, limestone, sand, shale
- Testing
  - Bits; PDC, impregnated diamond, baseline
  - Fluids; WBM, baselines, low solid dispersed
  - Rock samples; sandstone & limestone
- Drilling parameters
  - RPM, confining pressure, borehole pressure, pressure drop across bit, WOB, hydraulics

## Schedule and Conclusions

### *Schedule*

- Drilling Phase 1 (16 tests)  
Sept/Oct 2004
- Phase 2 – 2005 (16 tests)

### *Conclusions*

- High pressure readiness has taken a long time
- Industry Team has proposed program for 2 'applications'
- Large-scale testing will benchmark bits-fluids at pressures previously not studied
- Industry team input has been generous
  - Hughes Christensen diamond bits and INTEQ Fluids
  - Operators have provided 'applications' information



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The DOE and Hughes Christensen agreed to defer the DeepTrek project to early 2005 after Hughes encountered difficulties in delivering a new pumping unit before TerraTek's scheduled move to a new facility in Salt Lake City

To: Tim Grant, INTERNET:tim.grant@netl.doe.gov  
To: Alan Black, INTERNET:ablack@terratek.com  
CC: Arnis Judzis, INTERNET:judzis@terratek.com  
CC: Bland Ron, INTERNET:Ronald.Bland@bakerhughes.com  
CC: Pessier Rolf, INTERNET:Rolf.Pessier@hugheschris.com  
From: Sinor Allen, INTERNET:Allen.Sinor@hugheschris.com  
Date: 9/27/2004, 2:46 PM  
Re: RE: Potential Delay in Delivery of Mud Pump

We realize the burden the mud pump delay has placed on the project. We want to assure everyone that Mike McEntire (BETA) and Sean Berzas (Simulator) are working closely with the subcontractor to get all work completed asap. The mechanical issue though alarming, is all warranted to be satisfactory upon completion. Mike is at the subcontractor's yard today to get a full report.

The purpose of the Phase I benchmarking is to baseline drilling (and wear?) performance as we move forward in Phase II mud and bit design improvements. In our previous meetings, we did discuss a low end (180 gpm) and a high end (300 gpm). Looking at recent field runs, a flowrate of 220 - 240 gpm is typical, limited by mud pump surface pressures. These flowrates result in low hydraulic horsepower at the bit. I am not in favor of performing the tests at the lower end of the flow rate range. Bit balling, especially in the shales is a real problem at the lower flowrates. Surprisingly for most, there is also significant ROP effect with flowrate and HSI in harder permeable and non-permeable rocks.

HCC has invested significant expenditures for the high pressure fluid ends, pulsation dampers, etc. on behalf of TerraTek to meet phase I objectives. You may recall that the cost from National Oilwell was prohibitive. These pump expenditures to meet phase I deliverables will be unrecoverable if we do not proceed with Phase I as planned. Based on the available options from Alan Black and continued participation by HCC, Option 3 would be the most prudent.

Allen Sinor  
Technology Department

Hughes Christensen Co.  
281-363-6460 office

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

From: Alan Black [mailto:ablack@terratek.com]  
Sent: Monday, September 27, 2004 9:16 AM  
To: Tim Grant  
Cc: Sinor, Allen; Pessier, Rolf; Bland, Ron; Arnis Judzis  
Subject: Potential Delay in Delivery of Mud Pump

Tim Grant and Others,

On Friday, Hughes Christensen notified us that during the checkout testing of the mud pump that the diesel drive engine has a noise in the bottom of the engine and the control governor was not working. They have a diesel mechanic coming in today to evaluate the situation and they will let us know as soon as possible. Because it sounds like a potentially serious development, we wanted to propose the following options should there be a significant delay in obtaining the pump. We would prefer the first option, but depending on what is found out today, the other options might come into play. We would appreciate your input and approval of course.

Option 1-Carry out all of the Phase 1 testing with our mud pump at 180 gpm and use the higher flow rate 300 gpm on the Phase 2 testing. Hughes Christensen has indicated that 180 gpm is within the range that these size bits are run. A flow rate of 180 gpm would be on the low end, while the 300 gpm would be on the high end. For your information, we conducted a large JIP (DEA 90) on deep shale drilling with Pierre 1 shale and ran close to 75 tests with 6 1/2" diameter bits at 180 gpm and the results were quite good and replicated field performance quite well. The first series of test in DeepTrek relate to the Arbuckle formations. The harder formations used (Crab Orchard sandstone and Carthage marble) will not be very sensitive to flow rate. In the second series related to the Tuscaloosa formations, we will be drilling Crab Orchard sandstone (not very sensitive to flow rate) and Mancos shale (more sensitive to flow rate, but not as sensitive as the Pierre 1 shale used in the DEA 90 JIP). Hughes Christensen would need to supply us with a different set of bit nozzles should we decide to test with 180 gpm.

Option 2-Carry out the first series of Arbuckle tests at 180 gpm and then if the pump is then available the second week of October then carry out the Tuscaloosa tests at 300 gpm. Since the Arbuckle is a land operation, the rigs tend to have less pumping capacity and it would be more justified..

Option 3-Delay all DeepTrek Phase 1 testing until we have relocated to our new facility which would put the testing of into the December or more likely January time frame. Since we have already mixed the 11 ppg water-base drilling fluid, we would have to transfer it to the new facility and maintaining it for several months.

Also, with our relocation looming, we feel that any DeepTrek testing would have to be completed by the end of the 3rd week of October in order to meet our relocation schedule. We look forward to your input and further discussions with Hughes Christensen.

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Hughes Christensen rationale for both high pressure and high flow rate DeepTrek tests

To: Tim Grant, INTERNET:tim.grant@netl.doe.gov  
To: Alan Black, INTERNET:ablack@terratek.com  
To: Sinor Allen, INTERNET:Allen.Sinor@hugheschris.com  
CC: Arnis Judzis, INTERNET:judzis@terratek.com  
CC: Bland Ron, INTERNET:Ronald.Bland@bakerhughes.com  
From: Pessier Rolf, INTERNET:Rolf.Pessier@hugheschris.com  
Date: 9/29/2004, 7:38 AM  
Re: RE: Potential Delay in Delivery of Mud Pump

Allen,  
As we discussed yesterday I have attached the results of a series of simulator tests, which were run with a 6" diamond impregnated bit earlier this year. These tests were run with a 14 ppg water base mud at 6,000 psi bottomhole pressure in Crab Orchard sandstone and Mancos shale. The results show that the ROP is indeed highly dependednd on flow rate and HSI. I suspect the hydraulics become even more important at higher bottomhole pressure and higher mud weight.

Rolf

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## Coming up 4Q '04

- Update to 4Q 2004 meeting of the Drilling Engineering Association
- Technical Assessment for DOE project manager
- Request for no-cost contract extension

## CONCLUSIONS

- Task 1 project kick-off meeting with DOE personnel has been 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 Tuscaloosa drilling problems and review.
- Task 2 designs and engineering concepts for drilling at high pressure complete. A pre-drilling meeting was held November 19, 2003 and again May 25, 2004 to resolve any final issues.
- Task 3 will commence 1Q 2005 and is behind schedule due to delays with the Hughes pumping equipment. All large components are in place to proceed with high pressure drilling except pumping capacity for flow rates higher than 180 gpm.
- Task 5 was accommodated with a request by the DOE project managers and GTI to publish at the GTI February, 2004 meeting.

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