Extreme Drilling Laboratory (XDL)

XDL Overview
and
UDS Status Update

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Ultra-deep Drilling Simulator
Thank You!!
For your valuable contributions
Outline

• Background
• XDL
  – GeoLab (‘rock’) Overview
  – Fluids Lab Overview
  – Ultra-deep Drilling Simulator (UDS)
• UDS Status
• Shakedown Operations
• Future Plans
• Collaboration
Ultra-Deepwater & Unconventional Resources Program

(Epact 2005, Title IX, Subtitle J, Section 999)
“…to maximize the value of natural gas and other petroleum resources of the United States, by increasing the supply of such resources, through reducing the cost and increasing the efficiency of exploration for and production of such resources, while improving safety and minimizing environmental impacts.”
Challenges

Future Challenges include
- HPHT conditions
- Increased Safety and Environmental Concerns

Economically Feasible - Last 10% depth is 50% time, and cost.
Extreme Drilling Laboratory (XDL) Overview

Goal: Improve safety and efficiency of deep drilling

- **Ultra-deep Drilling Simulator (UDS)**
  - Conduct experiments and numerical modeling to enhance the fundamental understanding of the HPHT rock/cutter/fluid interactions

- **Fluids Lab**
  - Prepare fluid for UDS experiments
  - Conduct detailed pre-run and post-run analysis of fluid properties at HTHP

- **GeoLab**
  - Prepare rock specimen for UDS experimental studies
  - Conduct pre-run and post-run analysis of rock specimen and cuttings

XDL located at NETL’s Morgantown, WV. R&D Campus
GeoLab Overview

**Pre-Test Measurements**
- Hardness
- Strength
- Porosity
- Composition

**Post-Test Measurements**
- Cut Imaging
- Cutting – size distribution, and micro-structure analysis

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**Gamma Density**
The gamma density measures the variations in bulk density of the rock, which are correlated with variations in rock type, hardness, and rock strength.

**Natural Gamma Radiation**
Natural gamma is an indicator of rock composition, particularly the abundance of potassium, uranium, and thorium.

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**Multi Sensor Core Logger System**

**Strength Indexing System**

**Confocal Scanning Laser Microscope**
Fluids Lab Overview

Viscosity Measurements

Chandler Model 7600 Viscometer
- Max Temp (900°F)
- Max Pressure (40,000 psi)

Marsh Funnel Viscometer
Fann Model 35 Viscometer

Viscosity Measurement: Fluid in annulus between concentric cylinders. One cylinder rotates, the other measures forces exerted through the liquid.

Fluid Filtration Measurements
Filtration behavior and well cake-building characteristics of a drilling fluid affect the solids in the fluid and their interactions with each other and rock formation.

Fluid Aging Experiments
In the lab, an Aging Cell is used to subject fluids to high temperature

- HTHP Test Cell for Heat Aging
  - Typically, aging is for 16 hrs
  - Max Temp (650°F)
  - Max Pressure (1,500 psi)

FilterPress (low temperature, low pressure)
Complete HTHP Filter Press
Model 701ES Roller Oven
Ultra-deep Drilling Simulator (UDS)
Developed with TerraTek, a Schlumberger company, under DE-FC26-05NT42654

- One-of-a-Kind research facility
- Capability:
  - Single Cutter
  - Pressure up to 30,000 psi (200 MPa)
  - Temperature up to 480 °F (250 °C) – Planned Upgrade
  - Operates with drilling fluids
  - Visualization through X-Ray and High Speed video system
    - Images of cutting at down-hole conditions (i.e. HPHT)
    - X-Ray provides visualization of cutter and rock immersed in an optically opaque drilling fluid
- Operational 12 November 2010
UDS Functionality

Degrees of Freedom
- Cutter Selection
- Cutter Placement
- Rock Selection
- Drilling Fluid Formulation
- Shaft Speed (RPM)
- Depth of Cut

Controller Configuration
- Controller Maintains Depth of Cut and RPM for a defined length of cut
# UDS Capability Matrix

<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>2011 Phase I - Operating Value Limits</th>
<th>2012 Phase II - Operating Value Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bit Configuration Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutter Type</td>
<td>PDC</td>
<td>PDC</td>
</tr>
<tr>
<td>Cutter Shape / Orientation</td>
<td>(As Desired)</td>
<td>(As Desired)</td>
</tr>
<tr>
<td>Number of Cutters</td>
<td>One (1)</td>
<td>One (1)</td>
</tr>
<tr>
<td><strong>Sample-Related Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling Fluid</td>
<td>(As Desired)</td>
<td>(As Desired)</td>
</tr>
<tr>
<td>Rock Type</td>
<td>(As Desired)</td>
<td>(As Desired)</td>
</tr>
<tr>
<td>Maximum Core Diameter</td>
<td>8 in (200 mm)</td>
<td>8 in (200 mm)</td>
</tr>
<tr>
<td>Maximum Core Height (w. Cutter)</td>
<td>8.75 in (220 mm)</td>
<td>8.75 in (220 mm)</td>
</tr>
<tr>
<td>Maximum Actuator Stroke</td>
<td>4.5 in (114 mm)</td>
<td>4.5 in (114 mm)</td>
</tr>
<tr>
<td>Cell Internal Diameter</td>
<td>9.0 in (229 mm)</td>
<td>9.0 in (229 mm)</td>
</tr>
<tr>
<td>Cell Internal Height (No Load Cell)</td>
<td>29.0 in (736.6 mm)</td>
<td>29.0 in (736.6 mm)</td>
</tr>
<tr>
<td>Type / Effective Diameter of Sight</td>
<td>Quartz / 1.0 in (25 mm)</td>
<td>Sapphire / 1.0 in (25 mm)</td>
</tr>
<tr>
<td><strong>Environment Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>Ambient (68°F / 20°C)</td>
<td>480°F (250°C)</td>
</tr>
<tr>
<td>Maximum Confining Pressure</td>
<td>30 ksi (200 MPa)</td>
<td>30 ksi (200 MPa)</td>
</tr>
<tr>
<td>Monitoring Mode of Cut</td>
<td>High-Speed Digital Camera &amp; X-Ray System (Either per test)</td>
<td>High-Speed Digital Camera &amp; X-Ray System (Either per test)</td>
</tr>
<tr>
<td><strong>Control Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid Flow Rate</td>
<td>2 gpm (1.3 x 10⁻⁴ m³/s)</td>
<td>20 gpm (1.3 x 10⁻³ m³/s)</td>
</tr>
<tr>
<td>Rotational Speed of Sample</td>
<td>25 rpm</td>
<td>120 rpm</td>
</tr>
<tr>
<td><strong>Control Values</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutting Rate</td>
<td>0.001 to 0.125 in/s (0.025 to 0.635 mm/s)</td>
<td>0.001 to 0.625 in/s (0.025 to 0.635 mm/s)</td>
</tr>
<tr>
<td>Load Limit</td>
<td>20000 lbs (9 t)</td>
<td>20000 lbs (9 t)</td>
</tr>
<tr>
<td>Cutter Position – Distance from Center</td>
<td>2.38 to 3.63 in (60 to 92 mm)</td>
<td>0.50 to 3.75 (13 to 95 mm)</td>
</tr>
</tbody>
</table>
UDS – Visual Access into Cell

- Retainer Nut
- Retainer Tube (1.00" ID)
- Sight Glass Holder
- Sight Glass: Quartz / Sapphire Inset (1.75" OD)
- Packer Seal Assembly

Dimensions:
- 6.80"
- 3.26"
- 1.25"
- 2.62"
UDS Status

• Checkout of system components is complete
  – Vessel Pressure Test 45ksi
  – Leak Check 30ksi
  – MTS Control System Verification

• Conducting Shakedown Operations for characterizing and tuning UDS performance
  – Fluid: Mineral Oil - Paratherm
  – Rock: Fine grained limestone (Carthage Marble)
  – Revolutions: 0-15 rpm
  – Temperature: Ambient
  – Pressure: 0-30ksi
  – Depth of Cut: 0.040 inches
Shakedown Operations (1 of 2)

- Excellent Linear Position Controls
  - Controller maintains position within 0.0005 inches during cut
Shakedown Operations (2 of 2)

- **Rotational Controls**
  - Low RPM due to 20 GPM Hydraulic capacity
  - Upgrade planned
  - Max RPMs will vary with pressure
  - Controller Tuning ongoing

- **High-Speed Video**
  - Clear fluids will be provided by Baker Hughes – Thank You!
  - Sapphire sight glass pair installed 1 Dec 10
  - Spacer for load cell to move the cutter down during HS video

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15 ksi; 10 RPM; .040” depth of cut; Cutter Position 3.5” from center
Future Plans

- **Q2 : Jan – Mar 2011**
  - Load Cell Recalibration
  - Xray System Video
  - Experiments 0-30ksi
  - Initiate Design Upgrades (RPM & Temp )

- **Q3-Q4 : Apr-Sept 2011**
  - Experiments 0-30ksi
  - Complete upgrade design
  - Initiate Installation of upgrades

- **Q1 : Oct-Dec 2011**
  - Complete Installation and Checkout HTHP System
Collaboration

• **Future DEA Participation**
  - Present UDS Test Results & Status Updates upon request
  - Discussions - What is important to DEA members for HTHP R&D using UDS?
  - Interest in Collaborative R&D?

• **Potential Mechanisms for Collaboration**
  - CRADA : A cost share mechanism where each party will provide a defined portion of the work – no money exchange.
  - Work for Others: Outside Entity (outside of Govt) will fully funds a defined R&D effort on the UDS
  - JIP : Multiple industry partners fully fund R&D on UDS
QUESTIONS?