Dual Gradient Drilling: Has Its Time Finally Come?

AADE Emerging Technologies Forum

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Chevron Deepwater BU
Project Manager, Dual Gradient Drilling Implementation

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Key Messages

- Deepwater Gulf of Mexico drilling is extraordinarily challenging
- Dual gradient drilling is the solution to the water depth-related challenges, and
- The Managed Pressure Drilling capabilities of the technology can solve a number of downhole problems related to annular pressure changes.
- What is DGD and why does it work?
- It’s been done before.
- We’re considering it again!
Deepwater Gulf of Mexico
Situation Today

- We routinely drill nearly “un-drillable” wells
  - >30,000’ deep
  - > 6,000’ water depth
  - > 9,000 MRI’s

- Narrowing of the PP/FG window and ECD’s lead to MANY tight tolerance casings

- New rigs capable of drilling to 40,000’ to enable industry’s large portfolio of deepwater projects

- We’re just about against “The Wall”

We’re nostalgic for the past!
The Solution

Dual Gradient Drilling is a Form of Managed Pressure Drilling

It Removes the Impact of Water Depth
We're Taking Water Out of the Way

Subsea MudLift Drilling Joint Industry Project

1996 through 2001
Single vs. Dual-Gradient Drilling

Conventional

Dual Gradient

Single Mud Weight

Heavier Mud w/ Seawater Above Mudline

Same Bottom Hole Pressure
Why Does It Work?

RKB

Seabed

Depth

Pressure, psi

Density

Conventional Mud Hydrostatic

Seawater Hydrostatic

Dual Gradient Mud Hydrostatic

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Casing Points – Dual Gradient

4 Casing Points

Seafloor

Depth

Seawater Hydrostatic

Dual Gradient Density at TD

Fracture Pressure

Pore Pressure

TD

Pressure
Casing Points – Dual Gradient

3 Casing Points

Seafloor

Depth

Seawater Hydrostatic

Dual Gradient Density at TD

Fracture Pressure

Pore Pressure

Pressure

TD
Application of Dual Gradient Drilling: Potential for Elimination of Casing Strings in Complex Wells

Potential Well Plan with DGD Application

Actual Casing Program

6 casing strings (yellow) potentially could have been eliminated had DGD technology been available.
Simplified Well Design Allows More Completion Opportunities

(Conventional) 5-1/2" Tubing 7" Tubing (SubSea MudLift)

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How Will DGD Improve the Deepwater Business?

ENHANCE SAFETY AND ENVIRONMENTAL PERFORMANCE AND RISK
- Much better detection, reaction and control of kicks, which WILL be smaller
- Inherently safer wells
- Better environmental footprint

REDUCE DRILLING COST AND RISK
- Fewer strings of casing to reach TD
- Virtual elimination of lost circulation due to ballooning formations
- Significant reduction in “hidden downtime”
- Better cement jobs/fewer squeezes

IMPROVE WELL INTEGRITY
- Reduced casing loads
- Greater completion integrity

IMPROVE WELL PRODUCTIVITY
- Designer completions will become possible

IMPROVE EXPLORATION PERFORMANCE
- Easier geological sidetracks
- More effective reaction to formation “surprises”

IMPROVE PREDICTABILITY
- Improved reliability/reduced downtime, leading to
- More predictable outcomes

• Lower $/BOE Cost
• Lower Minimum Economic Field Size
SubSea MudLift Drilling
Defined Major Components

- Subsea Rotating Device (SRD)
- Mud Return Line
- MudLift Pump (MLP)
- Drill String Valve (DSV)
The Hydril MudLift Pump is Driven by Seawater
Test System Pumped for Nearly 2 Years
Solids Pumping Capabilities

FLOAT EQPT
CUTTINGS

SAMPLE # 7
Well sloughings/Cavings

SubSea MudLift Drilling

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Drill String Valve (DSV) was Tested for LCM and MWD Signal Throughput
Subsea Rotating Device Testing

**SRD Housing**

*Purpose:* Provide a mechanical interface between the drilling mud in the well and the seawater in the riser. Also minimizes gas ingress to the riser. Insert below retrieves on drill string every trip.

**Stripper Element Testing**
Factory Acceptance Testing Began
Feb 28, 2001
Test Well Drilled in Aug/Sept, 2001

Diamond Offshore
Ocean New Era

2nd Generation, Built in 1975

Texaco Well
GC 136 #8
Shasta Prospect
Driller’s Subsea Controls
Control / Monitoring Screens
Equipment is Only Half the Challenge
12 to 15 Man-Years Required to Develop DGD Operations and Well Control Procedures

<table>
<thead>
<tr>
<th>Drilling Operations</th>
<th>Unchanged</th>
<th>Changed w/SMD</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Circulation</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2. Drilling ahead</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3. Connections</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4. Tripping</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5. Displacing drilling fluids</td>
<td>✓</td>
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<tr>
<td>6. Lost circulation treatment</td>
<td></td>
<td>✓</td>
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<tr>
<td>7. Wireline logging</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>8. Running casing</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>9. Running liner</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>10. Cementing casing</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>11. Cementing liner</td>
<td></td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>12. Balanced plug</td>
<td></td>
<td>✓</td>
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<tr>
<td>13. High pressure squeeze</td>
<td></td>
<td>✓</td>
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<tr>
<td>14. Stuck pipe procedures</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>15. Use and installation of packers</td>
<td></td>
<td>✓</td>
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</tr>
</tbody>
</table>
## ALL Well Control Operations Change

<table>
<thead>
<tr>
<th>Well Control Operations</th>
<th>Unchanged</th>
<th>Changed w/SMD</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Kick detection</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2. Basic well control with DSV (Driller's Kill)</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3. Basic well control w/o DSV: NO shut-in</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4. Basic well control w/o DSV: WITH shut-in</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5. Kick detection during tripping</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>6. Shut-in while tripping</td>
<td></td>
<td>✓</td>
<td></td>
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<tr>
<td>7. Trapped pressure management</td>
<td></td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>8. Volumetric well control</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>9. Lubrication kill</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>10. Stripping</td>
<td></td>
<td>✓</td>
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<tr>
<td>11. Bullheading</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>12. Shut-in while running casing</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>13. Test casing seat</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>14. Dynamic kill</td>
<td></td>
<td>✓</td>
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</tbody>
</table>
Training Materials and Process

- Pre-Spud Materials
- Basic SMD Training (DGD)
- Procedures Training
- Well Control Training
- Drilling Program
- Pre-Spud Materials
# Training Matrix

## Training Levels

<table>
<thead>
<tr>
<th>Position</th>
<th>Training Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced A</strong></td>
<td>Comprehensive understanding of all facets of DGD; ability to formulate, design and communicate DGD procedures and techniques</td>
</tr>
<tr>
<td><strong>Intermediate I</strong></td>
<td>Working understand of DGD concepts and relational impacts to drilling operations; ability to use knowledge to make real-time decisions regarding well and equipment</td>
</tr>
<tr>
<td><strong>Basic B</strong></td>
<td>Practical understanding of DGD as related to his/her job functions</td>
</tr>
</tbody>
</table>

## Position and Training Levels

<table>
<thead>
<tr>
<th>Position</th>
<th>Well Design</th>
<th>Well Control</th>
<th>Well Operations</th>
<th>Rig Operations</th>
<th>Equipment Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operator</strong></td>
<td></td>
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<tr>
<td>Drilling Manager</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I B</td>
<td></td>
</tr>
<tr>
<td>Drilling Superintendent</td>
<td>I I I B</td>
<td>B</td>
<td></td>
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<tr>
<td>Drilling Engineer</td>
<td>A A A B B</td>
<td>A</td>
<td>B B</td>
<td>I I I I I I I I</td>
<td></td>
</tr>
<tr>
<td>Rig Supervisor</td>
<td>I A A A I</td>
<td>B</td>
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<tr>
<td>Drilling Contractor</td>
<td>I</td>
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<tr>
<td>Rig Manager</td>
<td>A A A I I</td>
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<tr>
<td>Toolpusher</td>
<td>I A A A A</td>
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<tr>
<td>Drilling Engineer</td>
<td>I A A A A B</td>
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<tr>
<td>Driller</td>
<td>I I A A</td>
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<tr>
<td><strong>Others</strong></td>
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<tr>
<td>Subsea Engineer</td>
<td>I I A A A</td>
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<tr>
<td>Mudlogger</td>
<td>I B</td>
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<tr>
<td>Mud Engineer</td>
<td>I I I I I I I</td>
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<tr>
<td>Hydril Personnel</td>
<td>B B B A A</td>
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<tr>
<td>Regulatory Agencies</td>
<td>B A B I I</td>
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<tr>
<td>DGD Consultant</td>
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<tr>
<td>Partners</td>
<td>I I I I I I</td>
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</tbody>
</table>

## Equipment Maintenance

- Drilling Manager: I I I B
- Drilling Superintendent: I I I B
- Drilling Engineer: A A A B B
- Rig Supervisor: I A A A A
- Driller: I I A A
- Assistant Driller: B B A A
- Rig Mechanic: A I
- Derrickhand: B B B B
- Floorhand: B B B
Pre-spud and Training Included Rig Crews, Service Personnel, MMS, Operator Representatives and Engineers
Hoisting the MLP Through the Moonpool
Moving in BOP
Landing SMD/ LMRP on BOP
Heading Down with the MLP
Field Test SMD System and Riser

- Auxiliary Lines on riser
Running Mud Line
Gumbo Drilling

Gumbo Dogs
All Important Objectives Met

- Manage Bottom Hole Pressure at All Times
  - Constant inlet pressure mode (Drill)
  - Constant rate mode (Kick or Kill)
- Cuttings to Surface
- Verify Dual Gradient Operation Procedures
- “Kick” detected/shut-in <2 bbls
- All Equipment Operated as Designed
- Personnel adapted quickly, training paid off
- 90% of Field Test Objectives met
Taking Water
Out Of The Way

The Clear Leader