Controlled Mud Level Managed Pressure Drilling System for Use in Deep Water

INTSOK
Deepwater and Harsh Environments Seminar
November 10, 2016
St. John’s Canada
CONFIDENTIALITY

The information contained in this presentation is CONFIDENTIAL and is intended for INTSOK Seminar November 10, 2016, use only. Copyright of all published material including photographs, drawings and images in this document remains vested in Enhanced Drilling and third party contributors as appropriate. Accordingly, neither the whole nor any part of this document shall be reproduced in any form nor used in any manner without express prior permission and applicable acknowledgements. No trademark, copyright or other notice shall be altered or removed from any reproduction. Any unauthorized use; dissemination of the information or copying of this presentation in whole or part is prohibited.

DISCLAIMER

While the information contained in this presentation is believed to be accurate, Enhanced Drilling has not conducted any investigation with respect to such information. Enhanced Drilling, its officers, directors and/or employees, expressly disclaim any and all liability, and do not give any representations or warranties expressed or implied, related to or for the information contained in, or for omissions from, this presentation or any other written or oral communication transmitted to any interested party in connection with this presentation so far as is permitted by law. In particular, but without limitation, no representation or warranty is given as to the achievement or reasonableness of, and no reliance should be placed on, any projections, estimates, forecasts, analyses or forward looking statements contained in this presentation which involve by their nature a number of risks, uncertainties or assumptions that could cause actual results or events to differ materially from those expressed or implied in this presentation. Neither Enhanced Drilling, its officers, directors and/or employees, will have any liability to you or any other person resulting from your use of information contained in this presentation.
Controlled Mud Level
Subsea Pumping History
Conventional Top-hole Drilling
Cuttings Transport System (CTS)

- **Suction Module**
- 6in suction hose w/ROV connections
- **Umbilical to surface**
- **Subsea Pump Module (disk pump)**
- **Diffuser**
- 10in discharge hose w/ROV connections
RMR® Riserless Mud Recovery

Mud Return Line

Suction Module

Umbilical

Suction Pump Module
Controlled Mud Level (CML)

- Managed Pressure Drilling (MPD)
- CML is IADC designation
- Subsea Pump Module (SPM) installed on drilling riser
- Drilling fluid returned up separate Mud Return Line (MRL)
- Adjusting riser fluid level manages wellbore pressure profile

**Primary Barrier Envelope**
1. Drilling fluid

**Secondary Barrier Envelope**
1. Casing/cement
2. Wellhead
3. SS BOP
EC-Drill® Managed Pressure Drilling System

• A step-change technology: Enables operators to “drill the undrillable well”

• Controlled Mud Level (CML) system

• Allows operators control of bottom hole pressure to drill:
  o Narrow pressure windows in deep water
  o Underbalanced formation
  o Manage Equivalent Circulating Density (ECD)

• Safety enhancing, cost saving
Operations Statistics (as of 2015)

- Cuttings Transport System (CTS)
  - 454 operations
  - First deployment 1998 in Gullfaks field, Norway
  - CTS was first used in **Canada** by **Husky Oil in 2003**, on the White Rose field from the Glomar Grand Banks rig

- Riserless Mud Recovery (RMR®)
  - 272 operations
  - First deployment 2003 in West Azeri field

- EC-Drill®
  - 13 operations
  - First deployment 2012 Offshore Cuba
EC-Drill®
Controlled Mud Level MPD
CML Managed Pressure Drilling System

Sea Level

Marine Drilling Riser

MRL

1,200 ft typ (366 m)

Mud line
SS BOP

Modified Riser Joint
Suction Pipe
RIVs

Suction Pressure Sensor
CML Operation
System Components

- Topfill Pump
- Driller’s Cabin
- Return Flow Meter
- Umbilical Winch
- Control Container & Office Tool Container
- Deployment Trolley
- Modified Riser Joint
- SPM
- MRL
Rig Integration
Modified Riser Joint (MRJ)

- Docking plate with Guide pin
- 6” pin connector
- 2 x pressure sensors
- Protection & guide structure
- Riser isolation valves with ROV override, FSC

Typical MRJ

6.8 in. Riser outlet block
Moonpool – Equipment

- Launch and Retrieval System
- Office Tool Container
- Control Container
- Pump Module
- Subsea Pump Module

All content in this presentation is confidential and the property of Enhanced Drilling.
CMCD
Controlled Mud Cap Drilling

Alternative to
Pressurized Mud Cap Drilling
or
Floating Mud Cap
Challenges in Karstified Carbonates
Drill in Controlled Mud Cap (CMCD) mode

- Riser Level: static net – 500 lpm loss
dynamic net – 150 lpm loss
- Boost pump: 800 LPM HAM in
- Topfill pump: 200 LPM HAM in
- Mud pump: 1,000 LPM SAC in
- SPM: 500 - 850 LPM HAM out

HAM = Heavy annular mud
SAC = Sacrificial fluid - seawater
Riser Fluid Level

- Observe riser level
  - Higher level = Higher Hydrostatic Pressure
  - Higher Hydrostatic pressure overbalance versus reservoir pressure increases downward mud velocity
- Change level
  - Adjust topside pumps
  - Achieve higher downward mud velocity in BHA/Hole annulus than upward gas migration velocity
## CMCD Results: Minimum Downward HAM Velocity – Stop Gas

### Pipe in Hole

<table>
<thead>
<tr>
<th>CASE</th>
<th>ANN INJ RATE</th>
<th>FLOW VELOCITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(l/min)</td>
<td>(gpm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>73</td>
<td>19.4</td>
</tr>
<tr>
<td>3</td>
<td>293</td>
<td>77.5</td>
</tr>
<tr>
<td>4</td>
<td>367</td>
<td>96.9</td>
</tr>
<tr>
<td>5</td>
<td>440</td>
<td>116.2</td>
</tr>
<tr>
<td>6</td>
<td>513</td>
<td>135.6</td>
</tr>
<tr>
<td>7</td>
<td>587</td>
<td>155.0</td>
</tr>
<tr>
<td>8</td>
<td>660</td>
<td>174.4</td>
</tr>
<tr>
<td>9</td>
<td>733</td>
<td>193.7</td>
</tr>
<tr>
<td>10</td>
<td>807</td>
<td>213.1</td>
</tr>
<tr>
<td>11</td>
<td>880</td>
<td>232.5</td>
</tr>
<tr>
<td>12</td>
<td>953</td>
<td>251.9</td>
</tr>
<tr>
<td>13</td>
<td>1027</td>
<td>271.2</td>
</tr>
<tr>
<td>14</td>
<td>1100</td>
<td>290.6</td>
</tr>
</tbody>
</table>

### Gas migration

- **Min:** 0.35 ft/sec
- **Max:** 0.55 ft/sec

---

**From Blade Energy Analysis/Report**
# CMCD Results: Minimum Downward HAM Velocity – Stop Gas

## No Pipe in Hole

<table>
<thead>
<tr>
<th>CASE</th>
<th>ANN INJ RATE</th>
<th>FLOW VELOCITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(l/min)</td>
<td>(gpm)</td>
</tr>
<tr>
<td></td>
<td>(gpm)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2</td>
<td>73</td>
<td>19.4</td>
</tr>
<tr>
<td>3</td>
<td>147</td>
<td>38.7</td>
</tr>
<tr>
<td>4</td>
<td>220</td>
<td>58.1</td>
</tr>
<tr>
<td>5</td>
<td>293</td>
<td>77.5</td>
</tr>
<tr>
<td>6</td>
<td>367</td>
<td>96.9</td>
</tr>
<tr>
<td>7</td>
<td>440</td>
<td>116.2</td>
</tr>
<tr>
<td>8</td>
<td>513</td>
<td>135.6</td>
</tr>
<tr>
<td>9</td>
<td>587</td>
<td>155.0</td>
</tr>
<tr>
<td>10</td>
<td>660</td>
<td>174.4</td>
</tr>
<tr>
<td>11</td>
<td>733</td>
<td>193.7</td>
</tr>
<tr>
<td>12</td>
<td>807</td>
<td>213.1</td>
</tr>
<tr>
<td>13</td>
<td>880</td>
<td>232.5</td>
</tr>
<tr>
<td>14</td>
<td>953</td>
<td>251.9</td>
</tr>
<tr>
<td>15</td>
<td>1027</td>
<td>271.2</td>
</tr>
<tr>
<td>16</td>
<td>1100</td>
<td>290.6</td>
</tr>
</tbody>
</table>

**Gas migration**

- **Min:** 0.35 ft/sec
- **Max:** 0.55 ft/sec

*From Blade Energy Analysis/Report*
Summary

• Logical progression of subsea bottom-hole pressure control
  • CTS > RMR > CML > CMCD
• CML represents a better approach to MPD
  • Narrow pore/fracture pressure windows
  • Depleted underbalanced formations
  • Controls ECD
• Equipment
  • Proven over many years and wells
  • Minimal rig integration requirements
  • Uses convention barriers and well control
• Progressing technology
Discover more at
www.enhanced-drilling.com