Managed Pressure Drilling (MPD) in Floating Drilling Operations

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Mud Margin in Deep Water Reservoirs

- Narrow pore- and fracture gradient margin
- Consequences:
  - Narrow mud weight window
  - More casing points
  - Well control problems
  - Escalating total well cost
MPD Methods

- Methods to keep well pressure constant through the operation
  - Connections
  - Tripping operations
  - Varying flowrate
  - Varying cuttings/gas content in mud

<table>
<thead>
<tr>
<th>Single Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Gradient</td>
</tr>
<tr>
<td>Choke</td>
</tr>
<tr>
<td>Choke + mud supply</td>
</tr>
<tr>
<td>CCS</td>
</tr>
<tr>
<td>SAC</td>
</tr>
</tbody>
</table>
Through Tubing Rotary Drilling (TTRD)

- Sidetrack through existing completion
- Small annular clearance
- High ECD
- Large Surge & Swab pressures
- MPD methods more attractive
Single Gradient MPD Systems
Dual Gradient MPD Systems

- Moving interface between mud and seawater
- Slower and less dramatic pressure response
Back Pressure Control MPD Systems

Depth

Seabed

Fracture pressure

Pore pressure

Pressure
Back Pressure Control MPD Systems

- Supplying mud through separate conduit gives flexibility
- Injection points may be:
  - Booster line
  - Upstream of the choke manifold
  - Kill / Choke line
Continuous Circulation MPD Methods

- Continuously circulate mud in the well
  - Circulation not interrupted by connection
Continuous Circulation System (CCS) MPD

- Circulate drillstring during connections
- Compensate by adjusting pump speed
- Pump rate may be limited
- Slower than normal connections

Ref: Maris International
Secondary Annulus Circulation (SAC) MPD

- Circulate down secondary annulus during connection
- Larger pump rates may be available
- Tripping out with drillstring circulation allows for faster tripping speed
Surge & Swab
Annular Friction Pressures

- Tripping into / out of well
  - Fluid displaced by drillstring
  - Fluid friction pressure drop
  - Surge / Swab pressures arise
- May exceed pore- & fracture pressures
- Tripping speed can be controlled
Drillpipe Connection

- Normally suspended from compensated crown
- Drillstring suspended from rotary table (non-compensated)
  - Follows rig heave motion ($\Delta L$)
  - Alternating Surge and Swab effects
Drillpipe Connection

- Heave motion
  - Amplitude
  - Period
- Pipe speed not operator controllable

<table>
<thead>
<tr>
<th>Amplitude ±(m)</th>
<th>Period (sec)</th>
<th>Max Velocity ±(m/s)</th>
<th>Surge/swab pressures ±(bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>11</td>
<td>0.29</td>
<td>10.18</td>
</tr>
<tr>
<td>1.0</td>
<td>14</td>
<td>0.45</td>
<td>14.00</td>
</tr>
<tr>
<td>1.5</td>
<td>11</td>
<td>0.86</td>
<td>24.32</td>
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<tr>
<td>3.0</td>
<td>13</td>
<td>1.45</td>
<td>55.63</td>
</tr>
</tbody>
</table>

Pipe Displacement

Bottom hole pressure variation due to surge/swab
Conclusions

- MPD methods may prove to be beneficial in a number of cases
  - Deep water
  - TTRD
  - Depleted reservoirs
- Heave motions can cause surge and swab pressures during pipe connections