A Probabilistic Approach to Risk Assessment of Managed Pressure Drilling in the Gulf of Mexico

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Managed Pressure Drilling

• **Not a new concept**
  - Slight departure from what we have historically been taught in well control school.

• **Not focused on the BHP**
  - Entire pressure profile in the open section of the hole which is not static but changes as drilling progresses

• **Not intended to maintain an overbalance over all sections, but to minimize departures outside the “pressure environment window”**.
  - Pore pressure or wellbore stability pressure on the low side
  - Frac or leakoff on the high side.
Managed Pressure Drilling

- Maintaining in real time mud density, equivalent circulating density and casing back pressure to control pressure throughout the exposed wellbore in a closed system.

\[ \text{MPD} = \text{MW} + \text{ECD} + \text{CP} \]
Spindletop

- Technology of its Day
  - Rotary Drilling
  - Drilling Mud
Closed Pressurized Mud System

- Surface pressure control head
- Real-time bottom hole pressure
- Computer controlled circulating system
- Continuous circulation with jointed pipe
Spindletop – A Step Change

The water which was flushed through the rotary dill pipe was failing to bring up the loose sands. Curt Hamill recognized that he had to increase the viscosity and density of the circulating fluid—but how? Hamill invented the world’s first drilling mud by driving some cattle through a shallow pond. The cattle stirred up the water enough to generate a thick mud. When the muddy water was poured down the Spindletop well bore, the hole was stabilized and the sands flushed out.

2003 EARTH SCIENTIST Magazine
MPD Prizes

• Real-time well control
• Reduce lost circulation and ballooning
• Reduce risk of stuck pipe
• Drill longer ERD wells with constant BHP
• Higher ROP in deep gas wells
• Control shallow gas and water flows
• Safer drilling environment
MPD – Size of the Prize?

$10\text{ million}?$
$100\text{ million}?$
$1\text{ billion}?$

The prize is big as you make it.

MPD is step-change technology.

\[
\text{MPD} = \text{MW} + \text{ECD} + \text{CP}
\]
What is Risk?

- Risk is the known chance that an event will occur.
  - Differentially Stuck while Drilling Well in GOM
- Risk = Probability x Severity

What is Uncertainty?

- Uncertainty is the unknown chance that an event will occur.
  - Don’t Know Where You Will Be Differentially Stuck while Drilling Well in GOM
Risk Assessment

• Risk Identification

• Risk Analysis
  – Qualitative
  – Quantitative

INTERNATIONAL ASSOCIATION
OF DRILLING CONTRACTORS
"Global Leadership for the Drilling Industry"

IADC Committees
Notices and meeting minutes for IADC Committees.
Government Affairs  Health, Safety & Environment  Training  Maintenance
Jackup Rig  Underbalanced Operations  Well Control; Information Technology
Solutions  Contracts  Rig Moving

Also: IADC Offshore Operating Division
Risk Analysis Process

- Scoring Models
  - Simple
  - Commensurate to the nature of expert opinion elicitation
- IADC Underbalanced Operations Committee
  - 2004 CHAIRMAN
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    - E-mail Address: ubochairman@iadc.org
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    - Managed Pressure Drilling (MPD) Subcommittee: Douglas Nunn, GlobalSantaFe
    - Daily Report Subcommittee: Inactive
Risk Analysis Process

• Scoring Models:
  - Qualitative scale of 1-10 for probability and impact estimations
  - Impact of a risk has been considered in 3 dimensions:
    • Impact on safety
    • Impact on cost
    • Impact on drilling efficiency
  - Overall impact is calculated by the weighted average of these three scores.
Risk Assessment Process Element

Risk Assessment
Estimate the frequency and consequences of potential incidents

Scoping and Screening Analysis
Define the physical and analytical boundaries of the assessment

Event Identification
Identify the events that could cause pipeline failures and lead to adverse consequences

Frequency Analysis
Estimate how often the events might occur

Consequence Analysis
Estimate the severity of the adverse impacts should the events occur

Risk Estimation
Combine frequency and consequence estimates into relative risk values

Risk Control & Decision Support
Select activities to reduce risk or produce equal or greater levels of safety more efficiently

Performance Monitoring & Feedback
Determine if the risk control decisions produce the anticipated outcomes
FMEA Criticality Analysis Index Codes

• Failure Mode and Effect Analysis
  – Severity
  – Occurrence
  – Detection
<table>
<thead>
<tr>
<th>Severity</th>
<th>Criteria</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous</td>
<td>Hazardous effect. Safety related. Sudden failure. Noncompliance with government regulations.</td>
<td>10</td>
</tr>
<tr>
<td>Serious</td>
<td>Potential hazardous effect. Able to stop product/service without mishap. Safety related. Time-dependent failure. Disruption to subsequent process operations. Compliance with government regulation is in jeopardy.</td>
<td>9</td>
</tr>
<tr>
<td>Extreme</td>
<td>Customer very dissatisfied. Extreme effect on process/service; equipment damaged. Product/service incomplete but safe.</td>
<td>8</td>
</tr>
<tr>
<td>Major</td>
<td>Customer dissatisfied. Major effect on service; rework on service necessary. Product/service performance severely affected but functionable and safe.</td>
<td>7</td>
</tr>
<tr>
<td>Significant</td>
<td>Customer experiences discomfort. Product/process performance degraded, but operable and safe.</td>
<td>6</td>
</tr>
<tr>
<td>Moderate</td>
<td>Customer experiences some dissatisfaction. Moderate effect on product or service performance.</td>
<td>5</td>
</tr>
<tr>
<td>Minor</td>
<td>Customer experiences minor nuisance. Minor effect on product or service performance. Fault does not require attention.</td>
<td>4</td>
</tr>
<tr>
<td>Slight</td>
<td>Customer slightly annoyed. Slight effect on product or service performance.</td>
<td>3</td>
</tr>
<tr>
<td>Very slight</td>
<td>Customer more likely will not notice the failure. Very slight effect on product / process performance.</td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>No discernible effect on product or subsequent processes.</td>
<td>1</td>
</tr>
</tbody>
</table>
## Occurrence Index

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>Criteria</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Certain</td>
<td>Failure almost certain.</td>
<td>10</td>
</tr>
<tr>
<td>Very High</td>
<td>Very high number of failures likely.</td>
<td>9</td>
</tr>
<tr>
<td>High</td>
<td>High number of failures likely.</td>
<td>8</td>
</tr>
<tr>
<td>Moderately High</td>
<td>Frequent high number of failures likely.</td>
<td>7</td>
</tr>
<tr>
<td>Medium</td>
<td>Moderate number of failures likely.</td>
<td>6</td>
</tr>
<tr>
<td>Occasional</td>
<td>Occasional number of failures likely.</td>
<td>5</td>
</tr>
<tr>
<td>Slight</td>
<td>Few failures likely.</td>
<td>4</td>
</tr>
<tr>
<td>Very slight</td>
<td>Very few failures likely.</td>
<td>3</td>
</tr>
<tr>
<td>Rare</td>
<td>Rare number of failures likely.</td>
<td>2</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Failure unlikely. History shows no failures.</td>
<td>1</td>
</tr>
</tbody>
</table>
## Detection Index

<table>
<thead>
<tr>
<th>Detection</th>
<th>Criteria</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Impossible</td>
<td>Absolute certainty of non-detection.</td>
<td>10</td>
</tr>
<tr>
<td>Very Remote</td>
<td>Very remote likelihood current controls will detect failure.</td>
<td>9</td>
</tr>
<tr>
<td>Remote</td>
<td>Remote likelihood current controls will detect failure.</td>
<td>8</td>
</tr>
<tr>
<td>Very Low</td>
<td>Very low likelihood current controls will detect failure.</td>
<td>7</td>
</tr>
<tr>
<td>Low</td>
<td>Low likelihood current controls will detect failure.</td>
<td>6</td>
</tr>
<tr>
<td>Moderate</td>
<td>Medium likelihood current controls will detect failure.</td>
<td>5</td>
</tr>
<tr>
<td>Moderately High</td>
<td>Moderately high likelihood current controls will detect the failure.</td>
<td>4</td>
</tr>
<tr>
<td>High</td>
<td>High likelihood current controls will detect failure.</td>
<td>3</td>
</tr>
<tr>
<td>Very High</td>
<td>Current controls will almost always will detect failure.</td>
<td>2</td>
</tr>
<tr>
<td>Certain</td>
<td>Current controls certain to detect.</td>
<td>1</td>
</tr>
</tbody>
</table>
Deliverables

- Extensive Report identifying and grading the risks involved between drilling in a conventional, overbalanced, open-system as we do now compared to drilling in a balanced, closed-system, managed pressure environment.
  - Shared among the participants
  - Serve as a basis to modify some of the regulatory limits placed upon drilling operations in the Gulf of Mexico.
Probability Distribution Function

Normal Distribution

Cumulative Distribution Function

Cumulative Distribution Function

Normal Distribution
Upside

• Anticipated long term economic benefits
  – Cost savings realized from less non-productive trouble time associated with drilling operations
  – Less damage to depleted or otherwise sensitive reservoirs, a potential reversal of recent trends to downgrade evaluation of reserves.
A Probabilistic Approach to Risk Assessment of Managed Pressure Drilling in the Gulf of Mexico

**MANDATE:**
To seek a fair, balanced and managed outcome by assessing an even handed comparison of risk between conventional drilling and managed pressure drilling.

**VISION:**
With open-minded regulatory agencies support develop an integrated, knowledgeable, open-minded, and proactive team to assist the industry in determining a future path forward.
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