Managed Pressure Drilling (MPD) Technologies and Drilling Risk Mitigation

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Conventional Drilling:
Open to the Atmosphere Drilling System

\[ \text{BHP} = \text{MW} + \text{Friction} \]

Only adjustments available with mud in the hole are pumps on, pumps off and pump speed.

Managed Pressure Drilling (MPD):
Closed System

\[ \text{BHP} = \text{MW} + \text{Friction} + \text{Backpressure} \]

Effective BHP can be changed significantly and quickly with fewer interruptions to drilling ahead.
Managed Pressure Drilling

• The International Association of Drilling Contractors defines MPD as “an adaptive drilling process used to more precisely control the annular pressure profile throughout the wellbore.”

• The objectives of MPD are:
  – to ascertain the downhole pressure environment limits,
  – to manage the annular hydraulic pressure profile accordingly.
Managed Pressure Drilling

- **Managed Pressure Drilling (MPD)** is more applicable to minimizing nonproductive time (NPT) risks associated with conventional drilling technologies.
- It does not invite influx but is equipped to contain any that might be incidental to the operation.
- MPD does use underbalanced equipment to more precisely manage the pressure profile throughout the wellbore.
- MPD can be used in conventional oil and gas applications, although it also has unique applications to coal bed methane, geothermal resources and drilling for commercial quantities of methane hydrates.
Rotating Control Device

- Equipment used to divert the annular flow of a well being drilled.
- Serves as a barrier between the well and rig floor at various amounts of annular pressure.
- Also called:
  - Rotating Control Head,
  - Rotating Diverter,
  - Rotating BOP,
  - Rotating Pressure Control Head.
- The industry standard for the RCD is called API 16RCD.
Scalable MPD Systems

SCALABLE SECURITY

Closing the Loop
Safety / Efficiency
- Divert fluid away from rig floor
- Allow slight reduction in mud weight
Visibility
- Influx or loss monitored by pit volumes only
Control
- Manual ECD control or conventional well control via BOP

Advance Flow Detection
Safety / Efficiency
- Instant detection – accurate mass balance monitoring
- NO CONTROL
Visibility
- Fingerprinting – Ballooning / Breathing / Kick / Loss
Control
- Manual ECD control or conventional well control via BOP

MPD - Microflux Control
Safety / Efficiency
- Instant detection, well control
- Manage backpressure
- Walk the line
Visibility
- Fingerprinting – Ballooning / Breathing / Kick / Loss
Control
- Pressure control via automated Microflux chokes
- Operations requiring only an RCD are common.
- Pressurized mud cap drilling operations make up the bulk of MPD operations requiring mainly an RCD.
- Closing the well in for safety with an RCD by diverting returns away from the rig floor.
- An RCD is also sometimes utilized to allow for movement of pipe with pressure on the well to avoid getting stuck.
RCD for Safety: Onshore

• The study “Recent Trends in RCD Usage and the Incidence of Blowouts” by Christopher J. Jablonowski and Augusto L. Podio, presented in the 2009 IADC Well Control Conference concluded that:
  • There is consistent statistical evidence, across a variety of regression models and variable specifications, that the use of RCD’s decreases the incidence of blowouts.
  • About six to seven out of ten onshore wells drilled in the USA utilize an RCD.
  • In certain instances, it is a requirement of underwriters to utilize a closed drilling system in order to enhance the level of safety of their drilling operation.
RCD Main Components

Marine Model 7875
RCD Docking Station

Bearing and Sealing Element Assembly

BART
Bearing Assembly Running Tool
RCD Bearing Assembly Installation
RCD Bearing Assembly Retrieval
RCD for Jack-Up / Tender Rig
The RCD Docking Station (DS) has top and bottom flanges that allow it to be installed in the marine riser system and remain connected to the rig at the diverter housing all times.

- Allows tie in to rig diverter system, greatly reducing the risk of spillage.

- The RCD bearing and packer assembly is installed through the diverter housing and marine riser system.
RCD Set-up on a Floater
RCD for Moored Semi-Sub (Funnel)
RCD for Moored Semi-Sub (TJ Tie-in)
Below Tension Ring (BTR) RCD

- 2000 psi Static Pressure Rating
- Installation in riser below waterline and above the termination joint.
- Tension rating is 3 million lbs.
- Gives the MPD system a higher pressure rating.
- Preserves the rig’s heave compensation system.
- Allows rig rotation by keeping MPD hoses away from tension lines.
- Safer MPD system installation.
Model 7875
Below Tension Ring (BTR) RCD

DSIT

Flow Spool
BTR-S (Slim) RCD

- Globally pioneering installation was recently successfully completed in offshore Malaysia.
- BTR-S RCD system integrated into the riser for Deepwater PMCD.
- Slim (19.0” OD) RCD bearing assembly and protective sleeve has been ran and retrieved and system was pressure tested with minimal problems.
BTR RCD With Bypass Lines

- Globally pioneering installation was recently successfully completed in offshore Angola.
- BTR RCD system integrated into the riser for Deepwater MPD operations with bypass lines installed through the MPD joint eliminates the need for rig to provide additional termination joint.
- Makes rig integration of MPD systems more unobtrusive.
**DW MPD System Components**

**Surface Components of Deepwater MPD System**
- Flow Diverting / MPD Manifold
- Surface Control System & HMI (for Manifold, MPD Annular & Flow Spool)

**Riser Integrated Components of Deepwater MPD System**
- Marine Series RCD
- MPD Annular
- Flow Spool
MPD Riser Joint Running

Step 12 of 12
Set Diverter in the housing and complete other rig up process as necessary.
Complete rig up.
Advanced Flow Detection System

• Closing in the well bore with an RCD in principle does not change anything as far as the physics of kick detection principles.
• Although level in the well cannot be seen, increase in return flow rate and in pit levels remain the most reliable indicators of a kick.
• Reliable mass flow meters and very accurate standpipe pressure sensors provide more precise and reliable kick detection system.
• Works in drilling, tripping or connections and during logging.
• Closing well and making it a pressure vessel enhances well control.
MPD System Flow Resolution

DRILLING
AUTO CONTROL: OFF

Tool Joints
Automated MPD System

Compatible with virtually any rig design, the Microflux™ system has a small surface footprint and few primary components.

Rotating control device (RCD). Used in a mud-return system to contain annular fluids while drilling, a RCD is a key enabler of MPD techniques; furthermore, it makes underbalanced, near-balanced and overbalanced drilling possible when facing an elevated risk of gas kicks. The Microflux system’s RCD has a secondary role, routing fluids through the control manifold, which is equipped with advanced sensory technology that extracts critical data from the fluids.

Weatherford recently received the industry’s first API 18 RCD certification for their RCD technology. The Model 7875 below-tension-ring RCD is the first to have the certification applied.

Mass flowmeter. The Coriolis mass flowmeter captures critical data—including mass and volume flow, as well as mud weight and temperature—from returning annular fluids in real time at a sample rate of multiple times per second. The data are routed to the system’s intelligent control unit.

Intelligent control unit (ICU). This independent SCADA control system houses all of the necessary data acquisition components for measuring and analyzing physical properties, including reacting to adverse well events. The ICU uses proprietary algorithms to identify minute downhole fluid inflows and losses; furthermore, it is capable of distinguishing between ballooning/breathing and more serious fluid inflows/losses and relays data to operator and redundant interfaces. When operating in automated mode, the ICU also controls the drilling chokes to regulate backpressure, as needed. The Microflux system’s ICU is compliant with all regulatory standards.

Proprietary algorithms promote safe practice by enabling kicks and losses to be detected, even during MPD operations such as maintaining backpressure on constant bottomhole operations. Alternative automated MPD systems use choke-position monitoring to assess the state of the well, which is less accurate and therefore less efficient in detecting kicks and losses.

Drilling chokes. The chokes open and close to regulate surface backpressure, essential to managing equivalent circulation density and consequently, controlling the wellbore’s pressure profile. The addition of a second, redundant choke reduces the potential for NPT.

Microflux control manifold

Weatherford Microflux™ Controlled
Automated MPD System – Next Gen
Automated MPD System Flexibility

• Drilling can be done under a variety of options:
  – Controlling flow out – manual or automatic
  – Controlling pressure – manual or automatic - BHP, surface back-pressure, stand pipe pressure, ….
  – Automatic kick detection and control – Pore pressure determination
  – Automatic loss detection and control – Frac pressure determination
  – Automatic detection of many common drilling events

• The only MPD system capable of doing all the above;
• The options above are selected based on a well’s design, problems, and its objectives. While drilling the system will change automatically to as the well encounters different environments.
MFC Applications

<table>
<thead>
<tr>
<th>Microflux™ Applications</th>
<th>Drilling Environments</th>
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<tbody>
<tr>
<td><strong>Wellbore and surface system monitoring</strong></td>
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<td>The Microflux system can be used to monitor multiple wellbore parameters—including pore pressure, equivalent circulation density, and surge/swell pressure—while drilling and making connections. This system can also be used to manage mud weight more effectively during tripping operations and to detect pipe washouts and surface leaks.</td>
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<tr>
<td><strong>Kick/loss detection and management</strong></td>
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<td>Beyond monitoring the wellbore pressure profile, the system can detect, confirm and (in automated mode) manage minute fluid influxes or losses. This capacity offers benefits in any drilling environment, but is especially valuable where there is a predetermined risk of kicks or fluid loss, or a margin of uncertainty where pore pressure or fracture gradient are concerned.</td>
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<td><strong>Constant bottomhole pressure (CBHP) drilling</strong></td>
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<td>In narrow pressure windows and ballooning scenarios, CBHP drilling enables operators to maintain a precise balance between pore pressure and fracture gradient—even when pumping stops—thereby ending problematic kick/loss cycles. The Microflux system’s enhanced ability to monitor and control the wellbore pressure profile facilitates CBHP drilling.</td>
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<td><strong>Pressurized mud-cap drilling (PMCD)</strong></td>
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<td>Another MPD variant, PMCD entails pumping heavy mud into the annulus to create a mud cap, which in turn enables drilling through severe loss zones using a less-costly drilling fluid, such as salt water. Fractures that absorb the so-called sacrificial fluid tend to plug, yielding an increasing pressure trend in pressure that could be interpreted as a kick. The Microflux system can help distinguish between routine fracture plugging and a kick. Used with PMCD techniques in sour reservoirs, the Microflux system also enables operators to manipulate flow rate and surface backpressure in a way that forces hazardous gas back downhole, where it can be pumped into the formation along with drilling fluid and cuttings, protecting wellsite personnel.</td>
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- Wellbore and Surface System Monitoring
- Early Kick / Loss Detection and Management
- Constant Bottomhole Pressure (CBHP) Drilling
- Pressurized Mud-Cap Drilling (PMCD)
Microflux Control Video
## Open vs Closed Drilling System

### Bubble Point above LMRP

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<tr>
<th>Open To Atmosphere</th>
<th>Closed Loop &amp; MPD</th>
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<tbody>
<tr>
<td>Detection: 20 bbl Kick</td>
<td>Detection: 1 bbl Kick</td>
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<tr>
<td>Identified too late</td>
<td>Identified at source</td>
</tr>
<tr>
<td>Gas breakout in riser</td>
<td>Automated response increases EMW (MW + friction + back pressure)</td>
</tr>
<tr>
<td>Rapid reactive response required – diverter or RGH</td>
<td>Rapid proactive response to primary well barrier to balance well</td>
</tr>
<tr>
<td>Shut in BOP &amp; well kill</td>
<td>Influx circulated out</td>
</tr>
<tr>
<td>GoM Statistic: 4.1 days average to control well</td>
<td>Continue drilling</td>
</tr>
<tr>
<td>90% of which are P&amp;A’d or sidetracked</td>
<td></td>
</tr>
<tr>
<td>GoM Statistic: 10.4 days fighting wellbore instability</td>
<td>Fingerprinting and drilling optimization</td>
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</tbody>
</table>

**MPD Detection & Response**
Deepwater MPD / RGRM Equipment
Mass Balance

Kick: Output > Input
Loss: Output < Input
Early Kick / Loss Detection & Control

- Influx Detected
- Recommendation: Apply Brake & Keep Pump Speed

- Flow In: 0 gpm, 0 ppg
- Flow Out: 100 gpm, 10 ppg
- Mud Wt. In: 0.8 ppg
- Mud Wt. Out: 0.8 ppg
- Back Pressure: 1000 psi
- High Limit: 1500 psi
- Standpipe Press: 1000 psi
- Bottom Hole Press: 2000 psi
- Sp. % Choke: 50%

- Pit Gain (BBL): 110
- Loss Gain: 96
- Gain: 14

- ROP: 0 fpm
- WOB: 0 lbs
- Hook Load: 0 lbs
- RPM: 0
- Pump 1 (SPM): 0
- Pump 2 (SPM): 0
- BHP Static: 1252
- Shoe Static: 1230
- BHP Friction: 10
- Shoe Friction: 10
- Hole Depth: 2800 ft
- Bottom Hole Pressure: 1777
- Casing Shoe Pressure: 1754
- Leak Off Test: 2143 psi
- 15.3 ppg
- 8.535 in
- 9.625 in
• Should Managed Pressure Drilling (MPD) and Riser Gas Handling (RGH) Systems be treated separately?
Riser Gas Handling vs MPD

- Riser Gas Handling (RGH) systems do not fully address the problem of gas in the riser.
- It requires manual intervention and time to close in the quick-close annular, as opposed to MPD where the well is already closed in and diversion can already and immediately be performed.
- Experiments and field deployments show that a DW MPD system can detect a gas influx immediately upon entry, before it dissolves in it and eventually get above the subsea BOP.
- In the ten deepwater MPD wells drilled in Indonesia, six influxes (<3 bbls) have been caught by MPD system.
- No instance of gas being able to break out in rig riser above subsea BOPs with DW MPD system installed.
• The MPD approach to addressing the issue of riser gas is centered on keeping it from reaching the riser instead of dealing with it once it is already there – prevention instead of cure, and is actually both.

• Keeping gas out of the riser is key.

• Only a DW MPD system provides a comprehensive and complete technological solution for riser gas.

• RGH systems that do not have an MPD component are at best a Band-Aid solution that does not fully remedy the festering wound that is the problem of riser gas.
Industry Acceptance of DW MPD

2003: Industry acceptance of MPD

April 20, 2010: Macondo

Safety

Efficiency

Drillability

How can I drill this well?

How can I improve the economics of this well?

How can I improve operational safety?
## Deepwater MPD Rig Integration

<table>
<thead>
<tr>
<th>Levels of MPD Readiness</th>
<th>Level 1: MPD Retrofit</th>
<th>Level 2: MPD Compatible</th>
<th>Level 3: MPD Ready</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPD – retrofit on floating rig fleet</td>
<td>14 months to implement</td>
<td>RGH compatible with Limited MPD</td>
<td>3 to 6 months to implement</td>
</tr>
<tr>
<td>MPD Plug &amp; Play</td>
<td>RGH compatible with Limited MPD</td>
<td>60 days to implement</td>
<td></td>
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<tr>
<td>MPD full integration</td>
<td></td>
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<tr>
<td>Technology</td>
<td>Open to Atmosphere drilling</td>
<td>Open to Atmosphere Drilling + Riser Gas Handling [flow spool, annular preventer, armored flexible flow lines, flow diversion manifold &amp; surface controls system]</td>
<td>Riser Gas Handling + Closed Loop Drilling (CLD) with Marine Series RCD &amp; Automated MPD Choke Manifold [chokes/flowmeter/surface controls system]</td>
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<tr>
<td>Benefits</td>
<td>Limited to conventional drilling</td>
<td>• Can handle larger gas volumes&lt;br&gt;• Additional barrier or protection&lt;br&gt;• Better control over diverter&lt;br&gt;• Minimal rig floor modification</td>
<td>Limited plug-and-play MPD implementation&lt;br&gt; • Can handle larger gas volumes&lt;br&gt;• Additional barrier or protection&lt;br&gt;• Better control over diverter&lt;br&gt;• Minimal rig floor modification&lt;br&gt;• Improved operational efficiency (NPT/drilling/rig up times)&lt;br&gt;• Limited moon pool rig up&lt;br&gt;• Full detection and management capabilities&lt;br&gt;• Enhanced well control&lt;br&gt;• Elimination of riser gas issues&lt;br&gt;<strong>Fully integrated MPD solution</strong></td>
</tr>
</tbody>
</table>
Deepwater MPD P&ID
MPD: Port Line to MFC
MPD: Port Line to Shakers
MPD: Starboard Line to MFC
MPD: Starboard Line to MGS
Pressure Relief: MPD CM
PMCD: With MFC
PMCD: No MFC
Riser Gas Management
Pioneering MPD System on a Dynamically Positioned Drillship Enables Safe Drilling of Rank Wildcat Deepwater Wells in Indonesia

Objective:
- Drill eight (8) rank wildcat deepwater wells in a safe and efficient manner from a dynamically positioned drillship equipped to perform MPD variations that address several drilling challenges.

Solution:
- An API16RCD-certified RCD was provided that can be installed below the tension ring (BTR) of the drillship and totally submerged in seawater for an extended period of time.
- Engineering, personnel and equipment for an automated MPD system and RCD were also supplied.

Value to Client:
- Microflux™ Control technology was successfully used to rapidly and accurately apply and manage backpressure for immediate detection and control of kicks.
- At the point where circulation losses could no longer be managed with the mud supply, the system was switched to pressurized mud cap drilling (PMCD) and well was drilled safely to its targeted depth.
- Well was subsequently logged safely through the RCD system despite of total loss of circulation.

Location
Makassar Strait, Indonesia

Water Depth:
Approximately 6,000 ft
• Globally, the installation of deepwater MPD systems will comprehensively address the risk of riser gas.
• Operators that have expressed interest on the use of the system are considering a full MPD deployment on the rigs being considered for use in their drilling campaigns.
• MPD provides riser gas risk mitigation capabilities, as well as operational efficiencies that will justify it economically, and provide additional options for drilling the difficult wells in their areas.
• MPD provides a viable alternative to open-to-the-atmosphere conventional drilling systems on the basis of safety, efficiency, economy and environment.
• Integration of MPD into deepwater rigs ultimately allows for the effective mitigation of drilling-associated risks.
Questions?

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