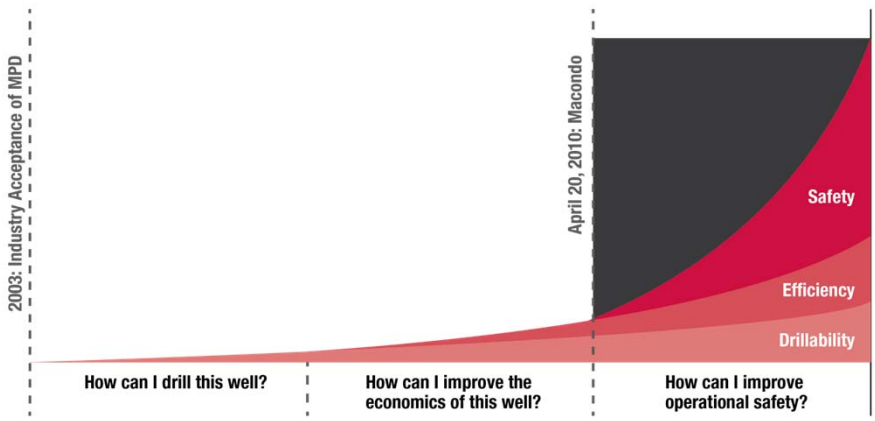
Offshore Vessel & Rig Connect Asia, April 20th 2016

Managed Pressure Drilling (MPD) The solution to undrillable reservoirs

James Riddoch – Sales and Marketing Manager, Asia Pacific

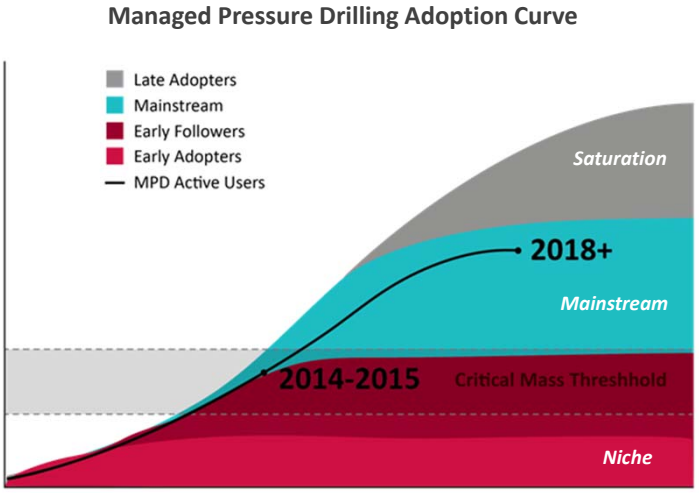
April , 2016

Past, Present and Future



Past, Present and Future

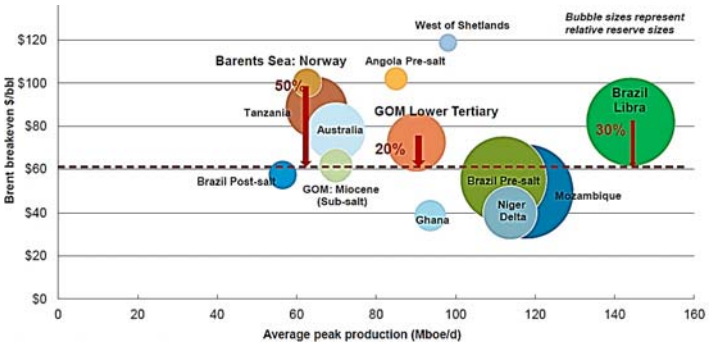
Deepwater technology adoption rate is projected to drive growth even in today's market.



DW MPD Integration: Industry-Wide

- **Operators** - key drivers for deepwater MPD rig integration projects, a majority of which are an outcome of operational requirements.
- **Rig contractors-** proactively planning and preparing for MPD rig integration to maintain a competitive advantage.
- **Shipyards/rig designers-** now incorporating MPD technologies into next-generation rig designs to expand client offering.

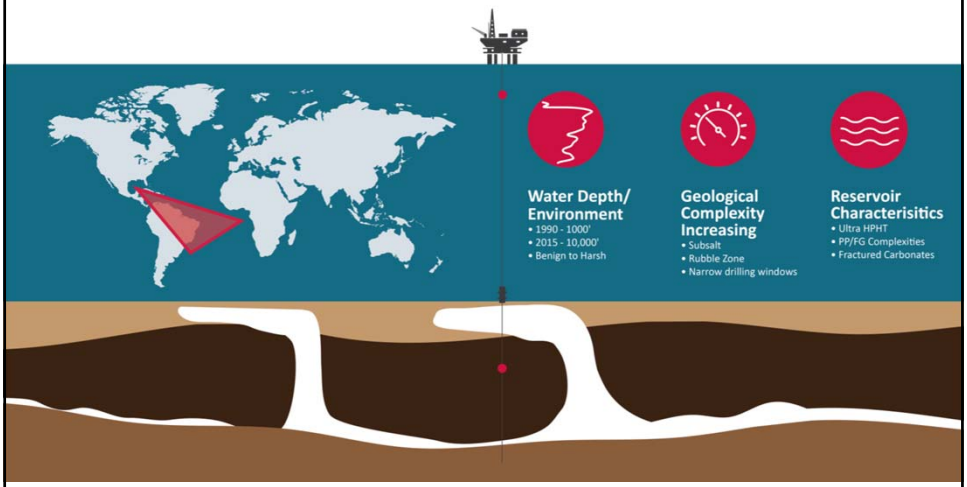
The New Pricing Reality



Average full-cycle economics (incl. E&A) Brent $/barrel for select unsanctioned deepwater plays at 2014 cost structure.

Source: IHS Global Deepwater and Growth Plays Service ©2015 IHS

Deepwater Challenges



MPD - Offshore

APPLICATIONS

MPD Definition

IADC Definition:

MPD is an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore.

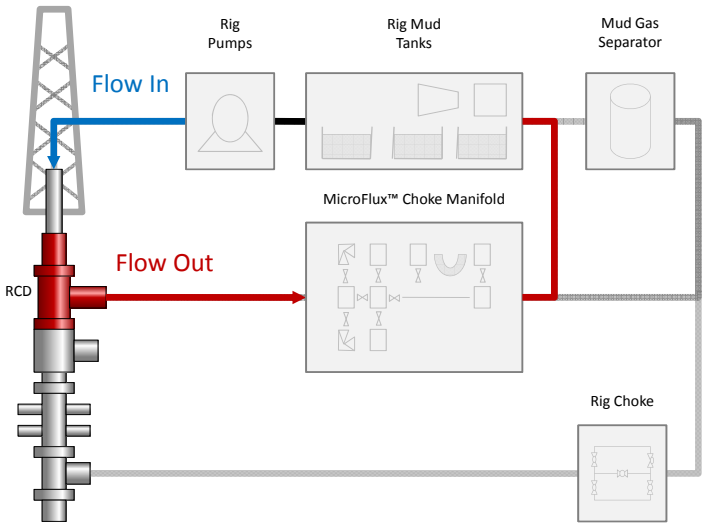
The objectives are:

- To ascertain the downhole pressure environment limits and to manage the annular pressure profile accordingly.
- To avoid continuous influx of formation fluids to surface. Any influx incidental to the operation will be safely contained using an appropriate process.

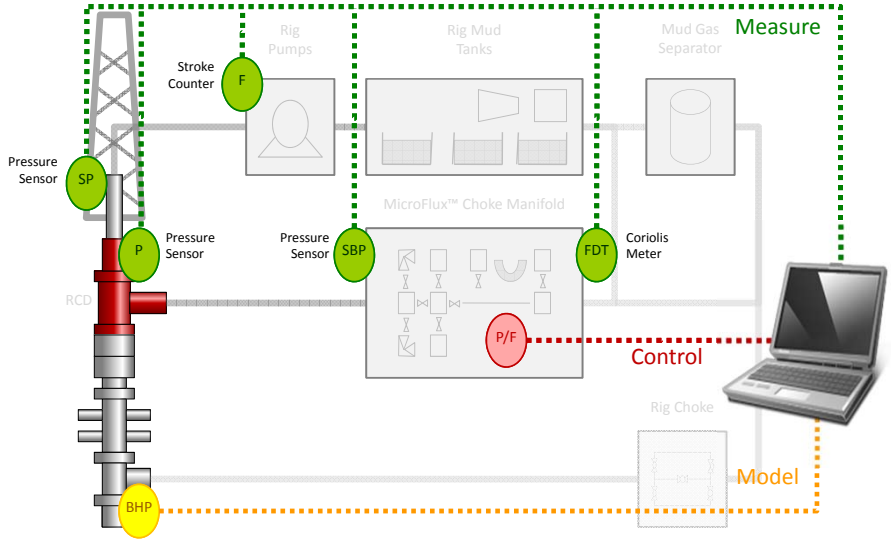
Conventional vs. MPD

CONVENTIONAL DRILLING Open to the Atmosphere System	MANAGED PRESSURE DRILLING (MPD) Closed System = Quick BHP Adjustments
Bottomhole Pressure (BHP) = Hydrostatic Mud Weight (MW) + Annular Friction	Bottomhole Pressure (BHP) = Hydrostatic Mud Weight (MW) + Annular Friction + Backpressure

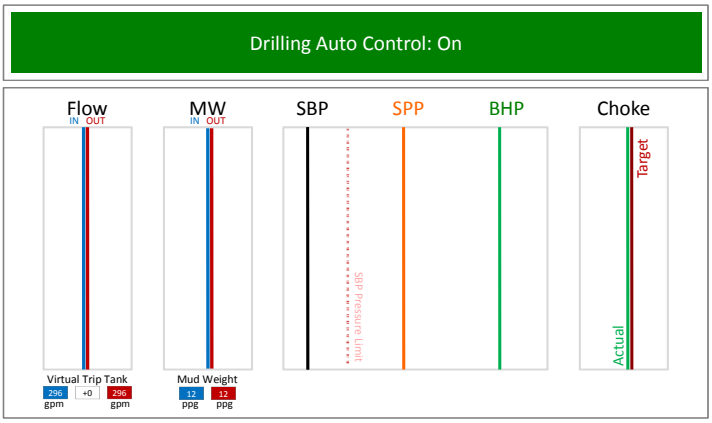
Secure Drilling Surface Equipment



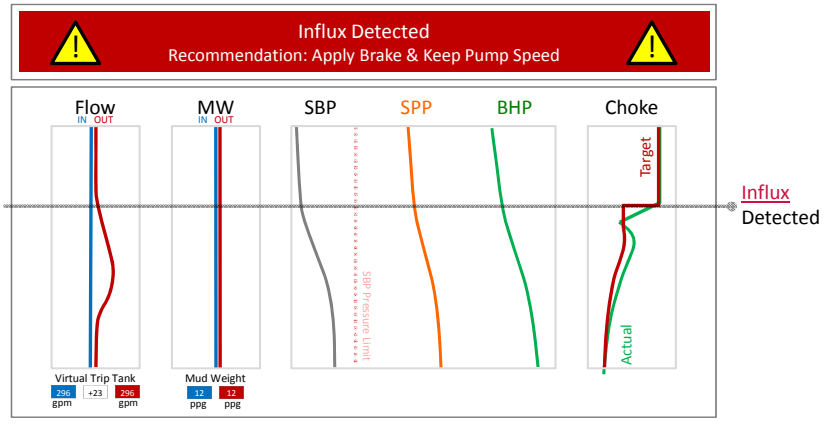
Secure Drilling System – Data Acquisition & Process Control



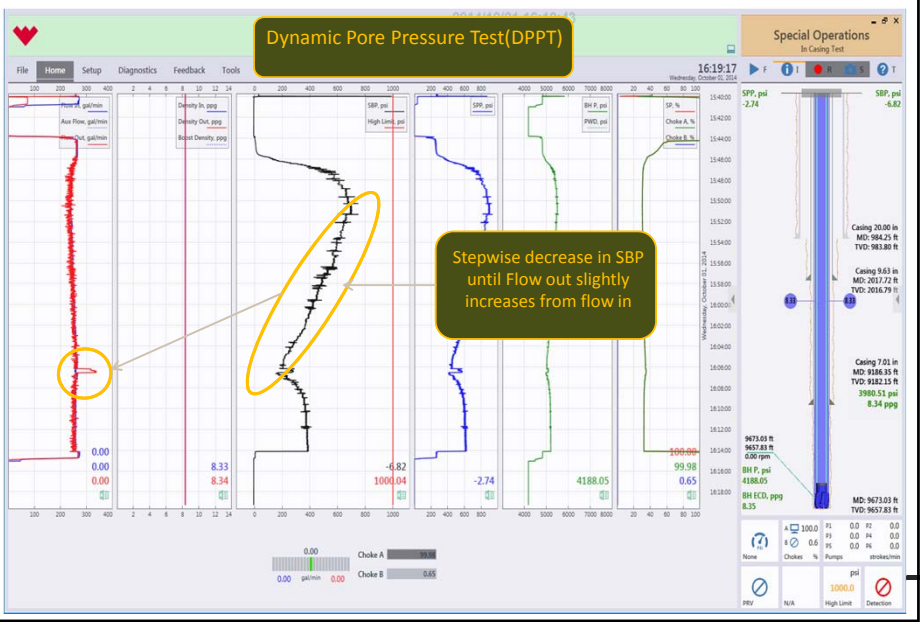
MPD MicroFlux™ Control – Kick Detection



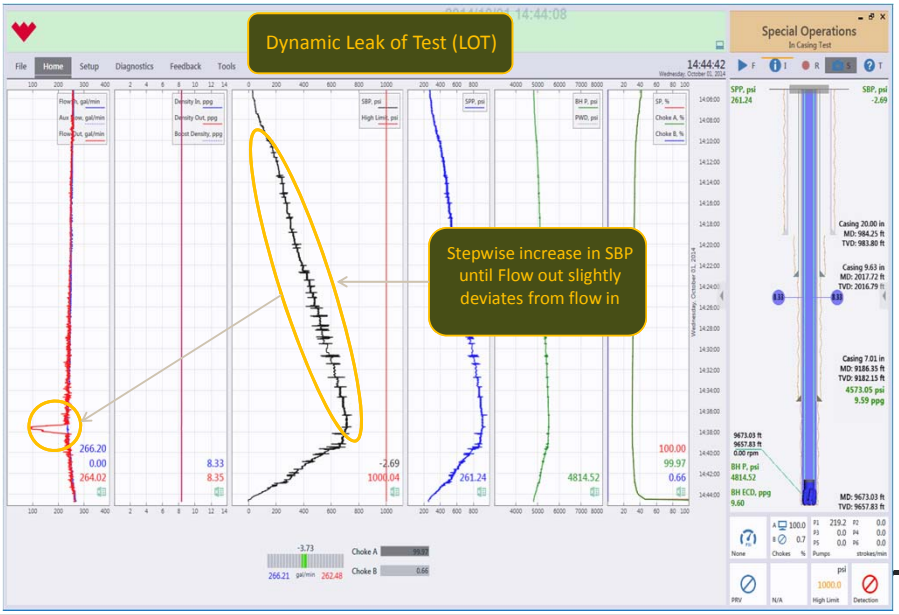
MPD MicroFlux™ Control – Dynamic Well Control



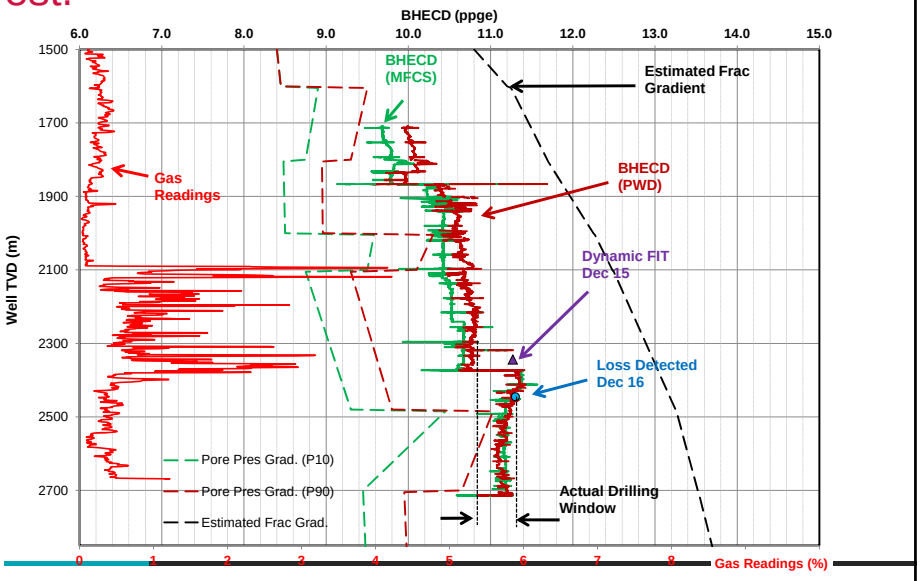
Well state – Dynamic Pore Pressure test



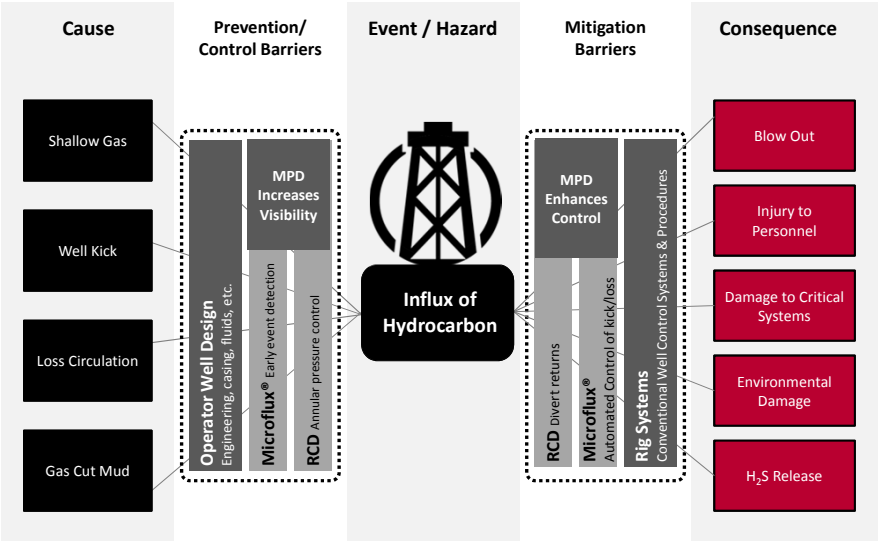
Well state – Dynamic LOT



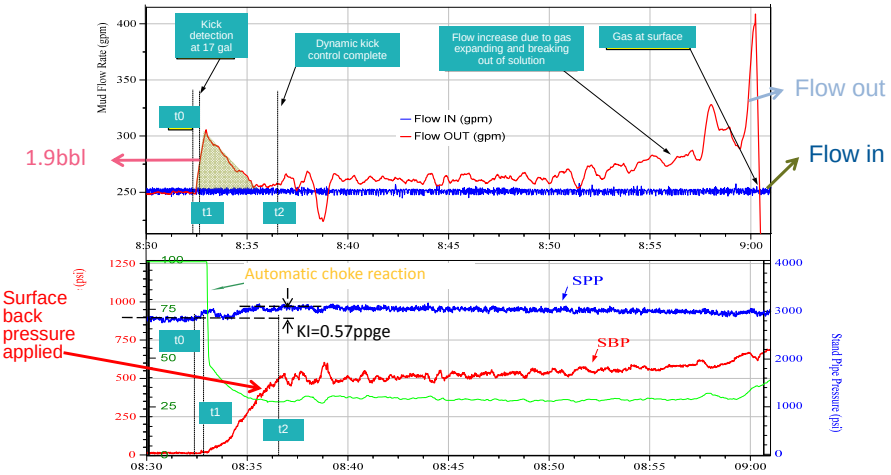
Drilling window case study – Actual vs. est.



Improves Safety, Efficiency & Cost



A Case Study Event: Automatic Kick Detection & Control by MPD System

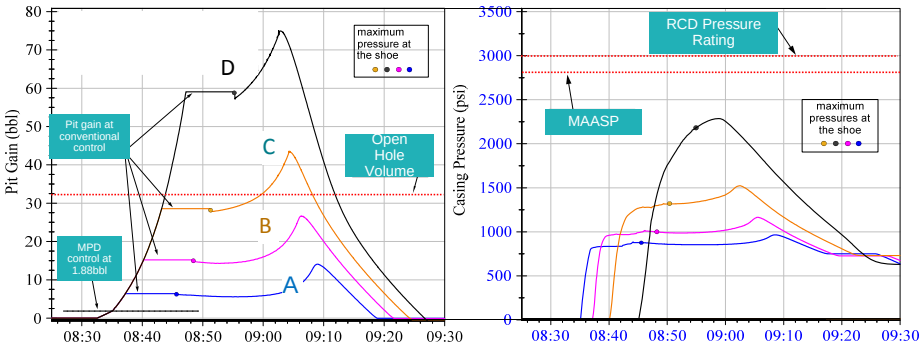


Drilling at 8,063ft MD w/ 10.3ppg OBM

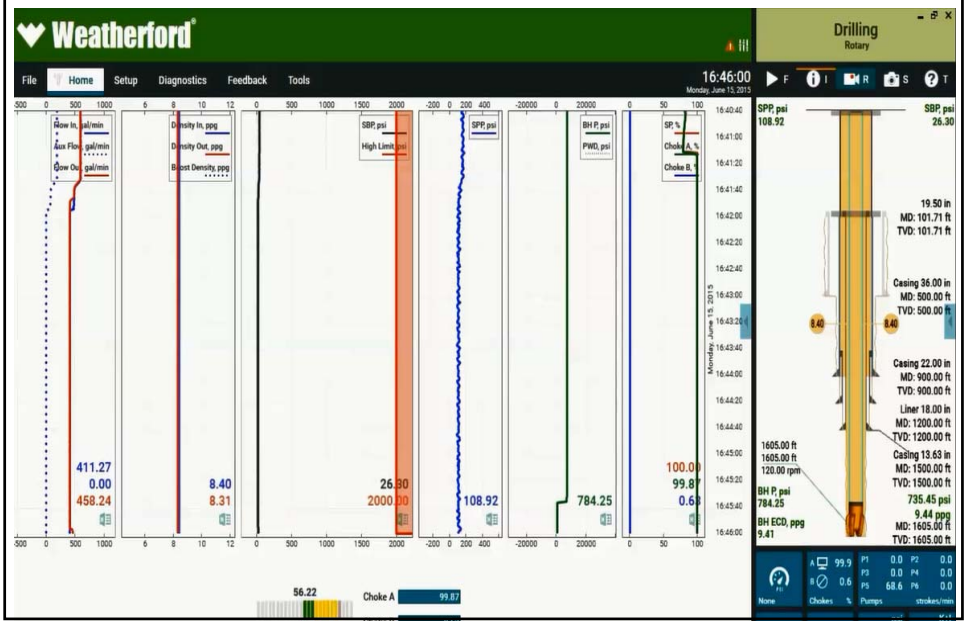
Analysis of the Conventional Kick Control

Next, sensitivity analysis was conducted applying the Driller's method of conventional well control for different *total response time* inputs.

	MPD Control	Conventional Well Control			
Simulation	I	A	B	C	D
Total Response Time, min	N/A	2	5	8	12



Early Event Detection and Control



Well Control Matrix

MPD Flow Control Matrix					Surface Pressure Indicators			
Influx Indicators	Influx State	Influx Rate	Influx Duration	Volume Gain	Planned Back Pressure For Drilling	Planned Back Pressure for connections	Planned back pressure limit exceeded but <70% of dynamic pressure of RCD	Back pressure exceeds >90% of dynamic pressure of RCD
	No influx	No influx	No influx	None	Continue Drilling	Continue Tripping and making connections	Increase BHP and reduce surface pressure to planned levels	Stop Drilling Shut in well on Rig BOP's and evaluate next action
	Steady inflow	< 0.1 bbl/min	< 1 min	< 0.5 bbls	Increase BHP and reduce surface pressure to planned levels	Increase BHP and reduce surface pressure to planned levels	Increase BHP and reduce surface pressure to planned levels	Stop Drilling Shut in well on Rig BOP's and evaluate next action
	Flow increasing	< 1 bbl/min	< 10 min	< 1.0 bbls	Stop Drilling Increase BHP and reduce surface pressure to planned levels	Stop Drilling Increase BHP and reduce surface pressure to planned levels	Stop Drilling Shut in well on Rig BOP's and evaluate next action	Stop Drilling Shut in well on Rig BOP's and evaluate next action
	Flow increasing Despite action	> 1 bbl/min	> 10 min	> 1.0 bbls	Stop Drilling Shut in well on Rig BOP's and evaluate next action	Stop Drilling Shut in well on Rig BOP's and evaluate next action	Stop Drilling Shut in well on Rig BOP's and evaluate next action	Stop Drilling Shut in well on Rig BOP's and evaluate next action

The thin red line between an “influx” vs. “kick”

Well & Flow Control Matrix → Ensures rig crew is aware of when action is required → Highlights when secondary well control is needed → Influx Indicators can be set for specific projects

MPD - Offshore

INTEGRATION

Deepwater MPD Integration Video

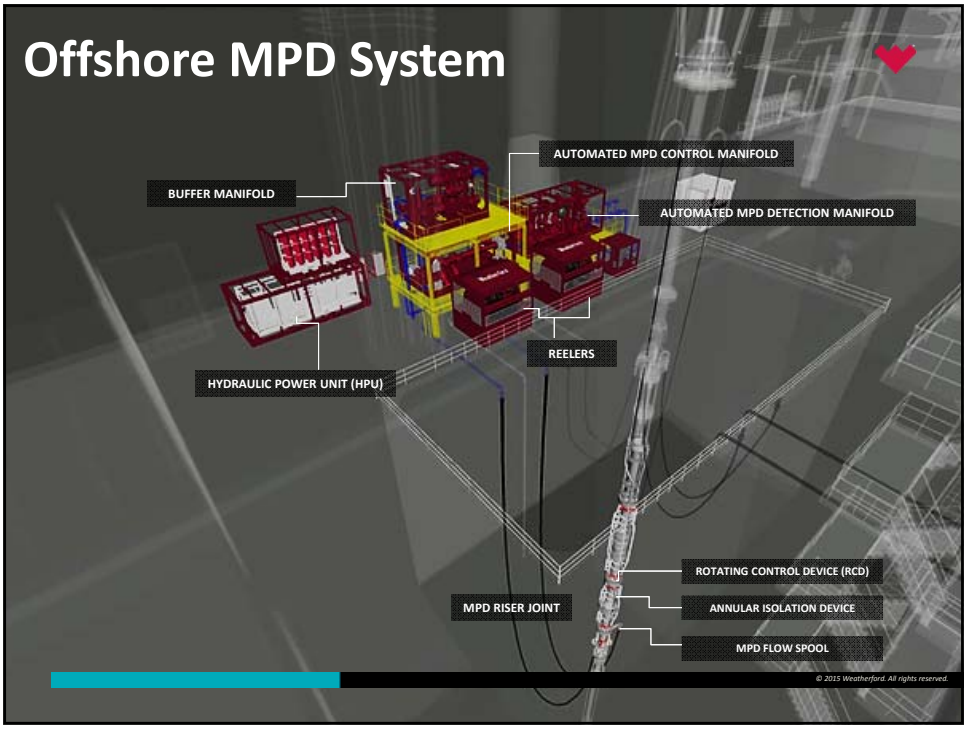
Deepwater Managed Pressure Drilling (MPD) Rig Integration.mov

2015: Drillship – BTR (BTJ)

Brunei/ Malaysia
Deepwater, integrated

- Deepwater, multi-well campaign
- Noble Bully II
- **MPD deepwater system** introduced
  - Aker clip riser adapters tailored for Noble Bully II & delivered prior to operations
  - New integrated MPD riser stack design will offer:
    - Reduced flat time
    - Significantly improved operational safety

Offshore MPD System



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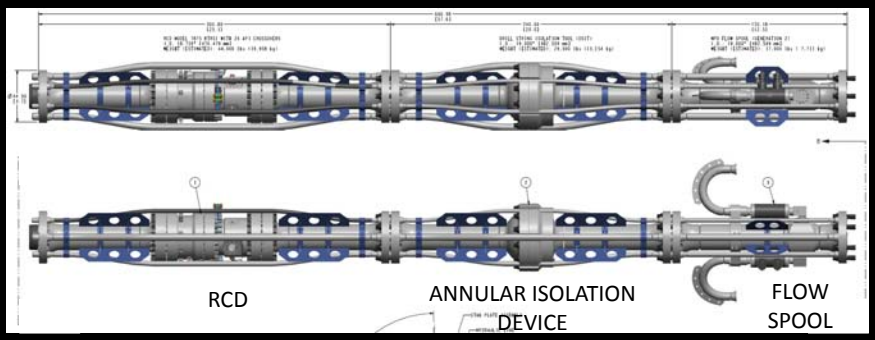
Salvo-Shook, D Constance, 01/12/2015

Deepwater MPD Riser Stack



Rotating Control Device (RCD)

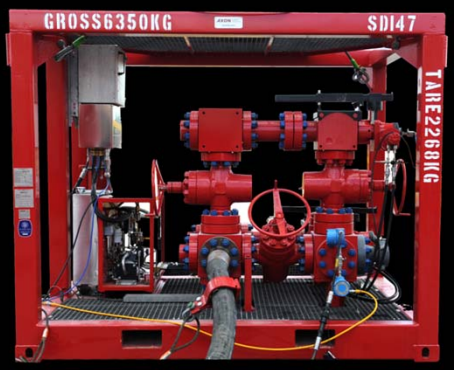
diverts the annular flow of a well being drilled.

An RCD serves as a barrier between the well and rig floor at varying amounts of annular pressure.

The industry-approved standard for an RCD is API 16RCD.

Automated MPD Manifolds

Detection



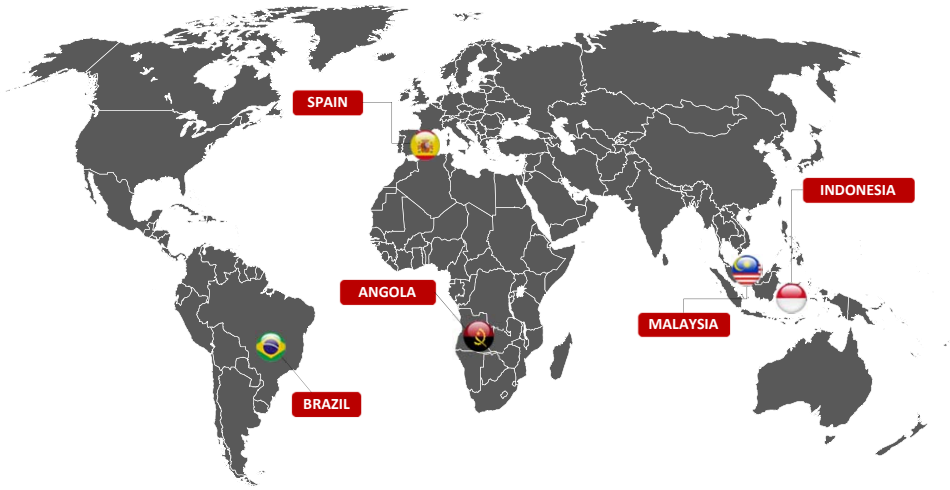
Control

OneSync™ Software Platform

OneSync ™ integrates hardware with software and enhances planning, simulation and control during MPD, EKD, and many other drilling and completions operations.

Photo courtesy of Maersk Training.

Deepwater MPD (BTR) Projects



30+ Deepwater MPD Wells | **20** DW MPD Rigs.

10+ Deepwater Contractors | **10** Deepwater Operators.

MPD: The New Drilling Convention

236 LAND **103** JACK UPS **51** FLOATERS

Proven. Accepted. Expected.

New Technology

OneSync™ Software Platform

Trend Monitoring

Analysis, Interpretation & Control

Optimization & Automation

OneSync™ Well Planning Software

Well Planning

Increase productivity with end-to-end well planning software.

- Built with MPD in mind
- Single database platform
- Synthesis of multiple modeling engines to improve pre-engineering simulations

Fluid Dynamics
Hydraulics
Well Control (Kick Analysis)

Geomechanics Analysis
Pore pressure prediction
Wellbore stability
Lithology
Overburden

Mechanical Analysis
Torque & Drag
Drill String Analysis
BHA Analysis
Directional

Cementing Simulation/ Analysis

Well Placement / 5D Seismic

OneSync™ MPD Simulation Software

- Model well control scenarios
- Time-based and depth-based plots
- Real-time engineering tools

Predict ahead and run what-if scenarios, based on the current well state

Training for MPD operations, real-time monitoring, & drilling optimization

Training & Development

Maersk: MPD Training Partnership

- **Maersk Training** partnership will deliver comprehensive competency and well-control training for MPD personnel worldwide.
- Program will fully integrate the **OneSync ™ platform** MPD simulator application into its drilling simulators to enable enhanced scenario-based MPD training and well-control

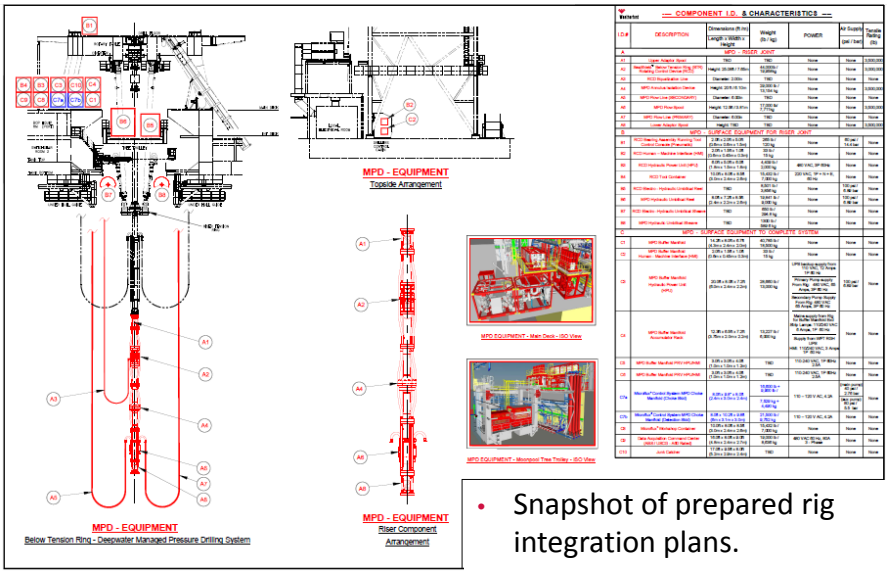
"We are combining strong technical knowledge with high-quality training to increase competence development for crews working with MPD technology. . .to improve safety and operational performance on rigs." **–Claus Bihl**, CEO of **Maersk Training**

Weatherford Microflux® Academy

The global **Microflux® Academy** prepares engineers and technicians with growth potential to become managed pressure drilling and Microflux experts.

QUESTIONS?

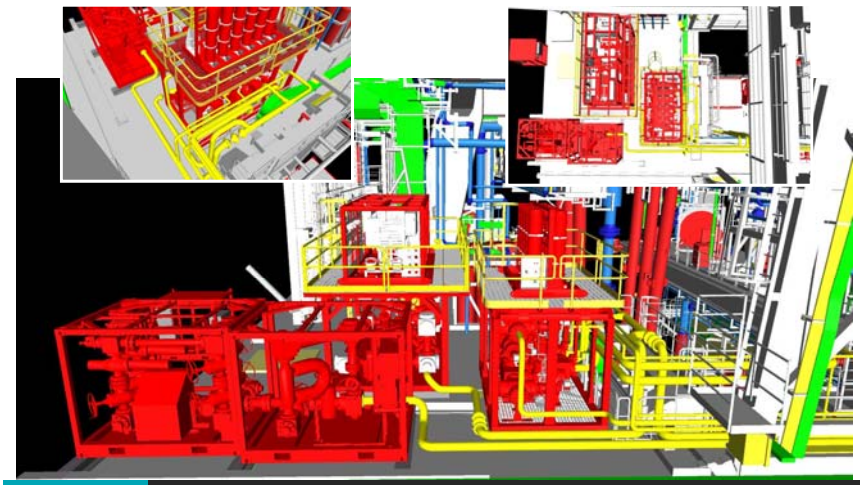
MPD Integration into a Floating Rig



- Snapshot of prepared rig integration plans.

MPD Integration into a Floating Rig

- Rig integration plans have been developed for numerous floating rigs in DW / UDW settings.

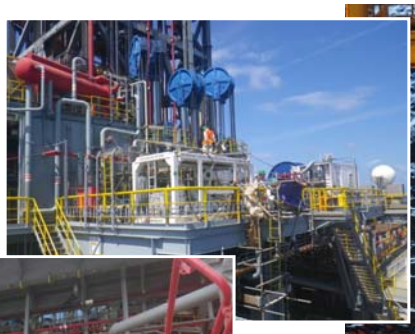


Retrofit Integration (Shipyard)

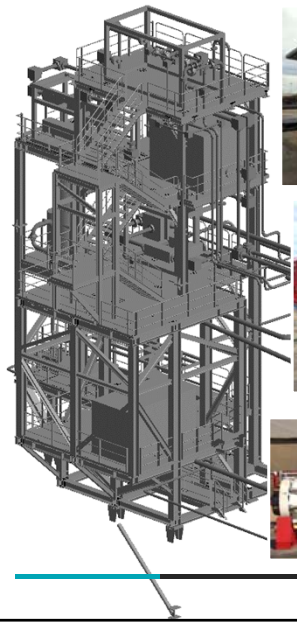
- MPD integration performed on shipyards and *in situ* for more than 20 deepwater rigs.

Retrofit Integration (In Transit)

Retrofit Integration (*In Situ*)

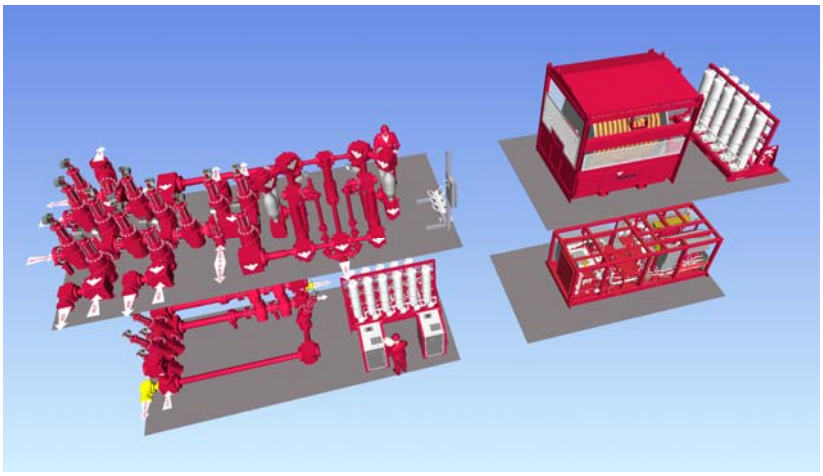




Retrofit Integration



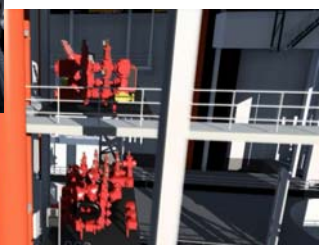



New Build Integration



- Development with ship builders of MPD designs for long-term permanent placement on deepwater drilling rigs.

New Build Integration



- Rig Design Integration Snapshots.

Deepwater (BTR RCD) MPD Experience

Deepwater Rigs That Have Deployed MPD Equipment

Rig		Year	Contractor	Operator	Rig Type	Max WD Rating	MPD Status as of today
GSF Explorer		2011	Transocean	Marathon	DS	7,800 ft	Scrapped
GSF Explorer		2011	Transocean	ConocoPhillips	DS	7,800 ft	Scrapped
GSF Explorer		2011	Transocean	Talisman	DS	7,800 ft	Scrapped
GSF Explorer		2012	Transocean	Statoil	DS	7,800 ft	Scrapped
Ocean Valor		2013	DODI	Petrobras	SS	10,000 ft	100% Ready
Ocean Monarch		2013	DODI	Niko Resources	SS	10,000 ft	25% Ready
Ensco 8504		2014	Ensco	Total / Shell	SS	10,000 ft	75% Ready
Rowan Renaissance		2014	Rowan	Repsol	DS	12,000 ft	50% Ready
Stena Carron		2014	Stena	Statoil	SS	10,000 ft	100% Ready
ODN Delba III		2015	Odebrecht	Petrobras	SS	7,800 ft	100% Ready
ODN 1		2015	Odebrecht	Petrobras	DS	9,000 ft	100% Ready
ODN 2		2015	Odebrecht	Petrobras	DS	9,000 ft	100% Ready
West Tellus		2015	Seadrill	Petrobras	DS	12,000 ft	100% Ready
West Carina		2015	Seadrill	Petrobras	DS	12,000 ft	100% Ready

Deepwater (BTR RCD) MPD Experience

Deepwater Rigs That Have Deployed MPD Equipment

Rig		Year	Contractor	Operator	Rig Type	Max WD Rating	MPD Status as of today
Noble Bully II		2015	Noble	Shell	DS	8,250 ft	100% Ready
Laguna Star		2016	QGOG	Petrobras	DS	10,000	100% Ready

MPD Status Legend:

100% - MPD Piping / Valving, Crossovers In Place; MPD Operations / Commissioning Performed
75% - MPD Piping / Valving, Crossovers In Process / In Place; MPD Operations Not Yet Performed
50% - MPD / RGH Piping / Valving In Process / In Place; Crossovers Not Available
25% - Rig Survey / Assessment Performed; Crossover Designs In Process or Available

Deepwater (BTR RCD) MPD Projects

Deepwater Rigs That Have Prepared to Deploy MPD Equipment

Rig		Year	Contractor	Operator	Rig Type	Max WD Rating	MPD Status
OR Mykonos		2016	Ocean Rig	Petrobras	DS	10,000 ft	75% Ready
OR Corcovado		2016	Ocean Rig	Petrobras	DS	10,000 ft	75% Ready
Lone Star		2016	QGOG	Petrobras	SS	7,880 ft	75% Ready
Gold Star		2016	QGOG	Petrobras	SS	9,000 ft	75% Ready
Amaralina Star		2016	QGOG	Petrobras	DS	10,000 ft	75% Ready
Brava Star		2016	QGOG	Petrobras	DS	12,000 ft	75% Ready
Amazonia		2016	Schahin	Petrobras	SS	7,874 ft	75% Ready
Pantanal		2016	Schahin	Petrobras	SS	6,560 ft	75% Ready
Norbe IV		2016	Odebrecht	Petrobras	DS	8,000 ft	75% Ready
Ocean Courage		2016	DODI	Petrobras	DS	10,000 ft	75% Ready
Saipem 10000		2016	Saipem	Eni / Petrobel	DS	10,000 ft	75% Ready
Ensco 8504		2016	Ensco	Kangean Energy	SS	10,000 ft	75% Ready
Dolphin Bolette		2016	Dolphin	Anadarko	DS	12,000 ft	50% Ready

Deepwater (BTR RCD) MPD Projects

Deepwater Rigs That Are Being / Have Been Considered to Deploy MPD Equipment

Rig		Year	Contractor	Operator	Rig Type	Max WD Rating	MPD Status
West Capricorn		2016	Seadrill	BP	SS	10,000 ft	25% Ready
West Eclipse		2016	Seadrill		SS	10,000 ft	25% Ready
West Taurus		2016	Seadrill		SS	10,000 ft	25% Ready
West Draco		2016	Seadrill		DS	12,000 ft	25% Ready
West Dorado		2016	Seadrill		DS	12,000 ft	25% Ready
West Eminence		2016	Seadrill		SS	10,000 ft	25% Ready
West Navigator		2016	Seadrill		DS	10,000 ft	25% Ready
West Rigel		2016	Seadrill		SS	10,000 ft	25% Ready
West Polaris		2016	Seadrill		DS	10,000 ft	25% Ready
Deepwater Asgard		2016	Transocean	Chevron	DS	12,000 ft	25% Ready
Noble Globetrotter 2		2017	Noble		DS	12,000 ft	25% Ready
Atwood Archer		2017	Atwood		DS	12,000 ft	25% Ready
OR Olympia		2017	Ocean Rig		DS	10,000 ft	25% Ready

Deepwater (BTR RCD) MPD Projects

Deepwater Rigs That Are Being / Have Been Considered to Deploy MPD Equipment

Rig		Year	Contractor	Operator	Rig Type	Max WD Rating	MPD Status
Quengela		2016	Sonangol		DS	12,000 ft	25% Ready
Libongas		2016	Sonangol		DS	12,000 ft	25% Ready
SSV Catarina		2016	Petroserv		SS	10,000 ft	25% Ready
Rowan Reliance		2016	Rowan		DS	12,000 ft	25% Ready
M. Venturer		2016	Maersk		DS	12,000 ft	25% Ready
Devt. Driller II		2016	Transocean		DS	10,000 ft	25% Ready
DW Pontus		2017	Transocean		DS	12,000 ft	25% Ready
Pacific Meltem		2017	Pacific		DS	12,000 ft	25% Ready
Pacific Khamsin		2017	Pacific		DS	12,000 ft	25% Ready
Pacific Mistral		2017	Pacific		DS	12,000 ft	25% Ready
Frigstad D90		2016	Frigstad		DS	12,000 ft	25% Ready

Real Results

Deepwater MPD System Installed *In Situ* Allows Highly Efficient Drilling Through Severe Losses in Carbonate Formations

Objective:

- Install a managed pressure drilling (MPD) system on location on a dynamically positioned semi-submersible within a very limited time frame while the rig is conducting deepwater drilling operations.
- Drill efficiently through karstified carbonate formations prone to severe circulation losses to isolate the same and access deeper target reservoirs.

Solution:

- Weatherford performed fast-track development of a slim version of the API16RCD-certified Seashield® Model 7875 below-tension-ring RCD to deployment through a 19.1" telescopic joint.
- Deep involvement with *in situ* MPD rig integration preparations.
- Engineering, personnel and equipment for automated MPD system utilizing Microflux control and SeaShield® RCD technologies were also supplied.

Value to Client:

- In situ deepwater MPD rig integration accomplished in less than six months.
- Drilling was switched to pressurized mud cap drilling (PMCD) in two consecutive hole sections that experienced severe losses and proceeded safely and efficiently, subsequently allowing for isolation of the same, facilitating access to the deeper target reservoirs.

LOCATION
Malaysia

Real Results

MPD Addresses Uncertainties and Risks Associated with Sub-salt Formations

Challenge:

- Reenter a plugged, cemented, and abandoned well in the deepwater pre-salt area of Brazil. The vertical well was situated in 6,562 ft (2,000 m) of water.
- Reach the targeted production zone at 16,781 ft (5,115 m), and mitigate fluid losses and a narrow drilling window.

Solution:

- Previous drilling encountered a severe fluid loss zone that consumed 600 bbl/hr (95 m3/hr). The cost of the fluid losses led to plugging and abandonment.
- MPD used until total losses experienced. The team switched to PMCD, which enabled the operator to maintain the drilling phase, manage the bottomhole pressure, and avoid massive mud losses. Target depth was reached and completion deployed.
- MPD revived a previously abandoned, multimillion-dollar investment. The well produces 20,000 B/D (3,180 m3), which earns the operator US $2 million per day.

LOCATION
Brazil, Santos Basin

WELL TYPE
Offshore, vertical

REASON FOR ABANDONMENT
Massive fluid losses while drilling

FLUID LOSS RATE
600 bbl/hr (95 m3/hr)

PLUG DEPTH
16,348 ft (4,983 m)

TARGET DEPTH
16,781 ft (5,115 m)

Real Results

Deepwater MPD Rig Integration Enables Safe, Efficient Drilling of Exploration Wells

Challenge:

- Deepwater MPD rig integration into the riser gas handling system of a dynamically positioned drillship *en route* to location.
- Upgrade the conventional drilling system on the deepwater rig to enable it to immediately detect, react to and exert control over pressure-related events in deepwater exploration wells to be drilled in environmentally sensitive areas.

Solution:

- Detailed MPD rig survey was performed while the rig was still under construction at the shipyard.
- Equipment installation and necessary rig modifications were performed while the drillship was en route to drilling location.
- MPD technologies enabled the operator to drill three hole sections of different sizes, avoid total losses, and manage nuisance gas in a challenging deepwater environment.
- Use of MPD resulted in safer and faster drilling performance that saved the operator significant time and costs.

LOCATION
Angola

WELL TYPE
Deepwater, gas

RIG TYPE
Drillship

HOLE SIZES
Section A: 18-1/8 in.
Section B: 14-1/2 × 16-1/2 in.
Section C: 12-1/4 in.

Real Results

Pioneering MPD System on Dynamically Positioned Drillship Enables Safe Drilling of Rank Wildcat Deepwater Wells in Indonesia

Objective:

- Drill 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:

- Weatherford provided an API16RCD-certified SeaShield® Model 7875 RCD 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 automated MPD system utilizing Microflux® Control and SeaShield RCD technologies were also supplied.

Value to Client:

- Microflux Control technology was successfully used to rapidly and accurately apply and manage backpressure to determine actual pressure profile of wells and allowed for immediate detection and control of kicks.
- When circulation losses could no longer be managed with the mud supply, the system was switched to pressurized mud cap drilling (PMCD). System allowed the deepwater well to be 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

Real Results

Managed Pressure Drilling Saves $18 Million in Challenging Deepwater Clastic Formation

Objective:

- Design a managed pressure drilling (MPD) system for a multiwell campaign.
- Drill through a clastic formation with a narrow mud-weight window while safely diverting gas to reach the target depth.
- Increase operational efficiency by using a mud weight less than the pore-pressure gradient during drilling and a bottomhole pressure higher than the equivalent circulating density (ECD) during connections.

Solution:

- Weatherford engineered and installed an MPD system on a moored DW rig.
- MPD system left existing flowlines intact and allowed reverting to conventional methods.
- The Microflux® automated MPD system enabled efficient drilling with a synthetic-based mud (SBM) weight lesser than pore-pressure gradient.

Value to Client:

- Installing MPD on first well in campaign saved 5 days and reduced drilling costs by approximately US$18 million compared to authorized amount.
- MPD helped the client navigate narrow mud-weight windows, maintain control of gas influxes, and reach target depth according to planned casing program, which would have been impossible using conventional methods.

LOCATION
Makassar Strait, Indonesia

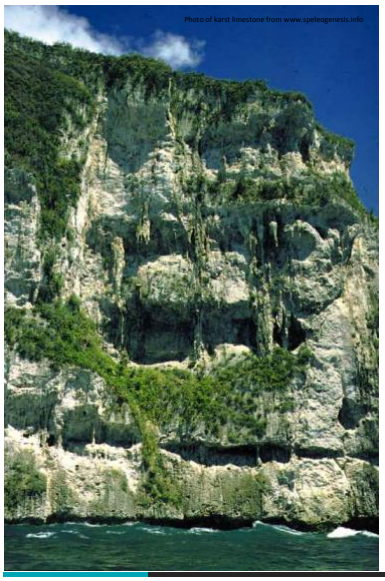
WATER DEPTH
Approximately 7,500 ft

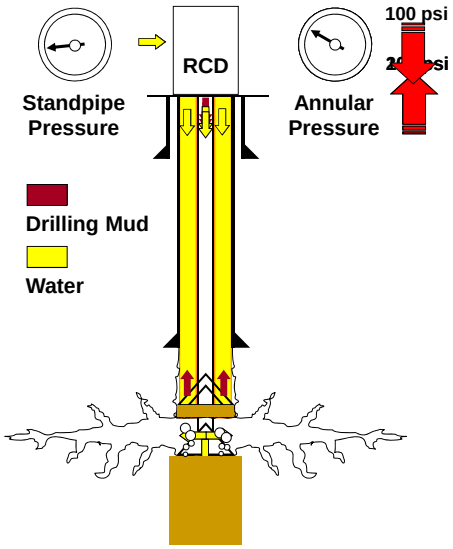
Pressurized Mud Cap Drilling (PMCD)

- MPD variant that drills without returns to surface.
- An annulus fluid column, assisted by surface pressure exerted with an RCD, is maintained above a formation able to accept fluid / cuttings.
- Useful for cases of severe circulation losses that preclude conventional drilling techniques.
- A sacrificial fluid with cuttings is accepted by the loss circulation zone.

SOURCE: IADC

Pressurized Mud Cap Drilling (PMCD)





PMCD Video