Subsea Pump System - Optimized for Rapid Deployment & Operation within the Primary Barrier

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Agenda

- Pumped Riser System (PRS) Vision
- Initial Concept
- Operational and Deployment Benefits
- Key Component Overview
- Stepping Stone to Full DGD
- Conclusion

Pumped Riser System (PRS) Vision

- The PRS is designed to control wellbore pressure by reducing the amount of riser pressure exerted on the wellbore

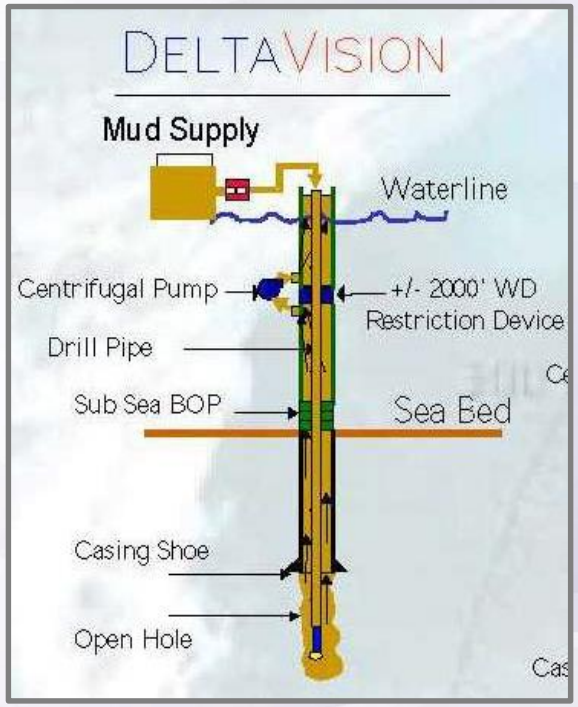
- In the short term, as an ECD control solution, the PRS has the following unique features
  - Maintains a full riser and statically balanced wellbore at all times.
  - Permits accepted static flow check and basic kick detection methods
  - Does not require riser depletion/refill on connections
  - Rotary table deployable system, with low power requirement
  - Conventional riser joints maintained, no modifications required
  - Enables a rig to be MPD-Prepared simply by procuring riser crossovers in advance and MPD-Operational in 2 weeks

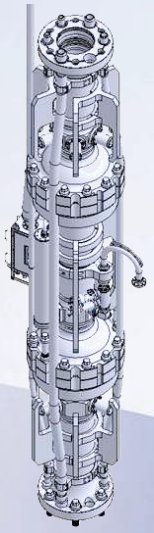
- The PRS module is seen as a stepping stone to achieving a full Dual Gradient Drilling (DGD) solution

- The PRS can be utilized independently or as a complimentary module to an Applied Surface Back Pressure (ASBP) MPD System

15+ Years of Conceptual and Proven Technology Development

Initial Concept



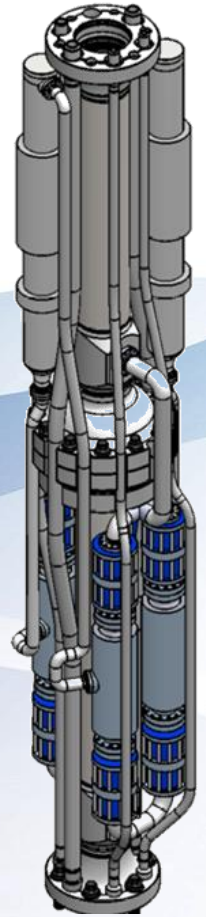


MPD Wellbore Sealing System (Active)

2002 – 17+

Subsea Pump System (Positive Displacement)

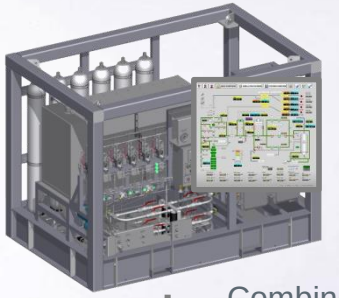
Mid-Riser Pump System



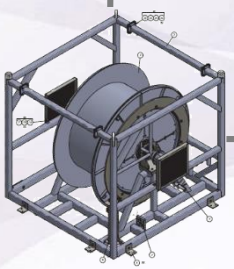
Pumped Riser System – ECD Control

Driller Screen

Tool Pusher Screen

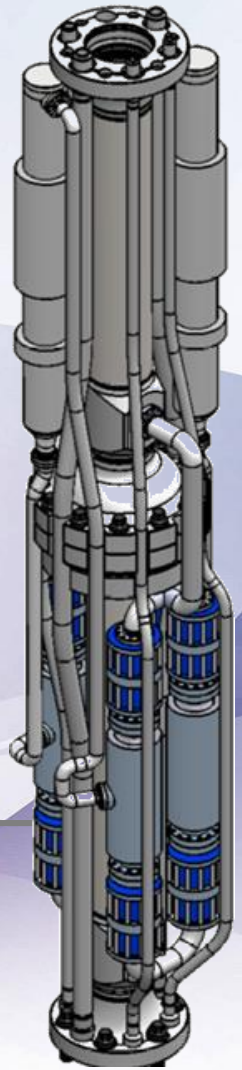


Combined Hydraulic Power Unit & Pump Controller



Umbilical Reel

Umbilical



PRS max riser installation depth 1640’ [500m], Exceeds required depth

2 X Drive Motors

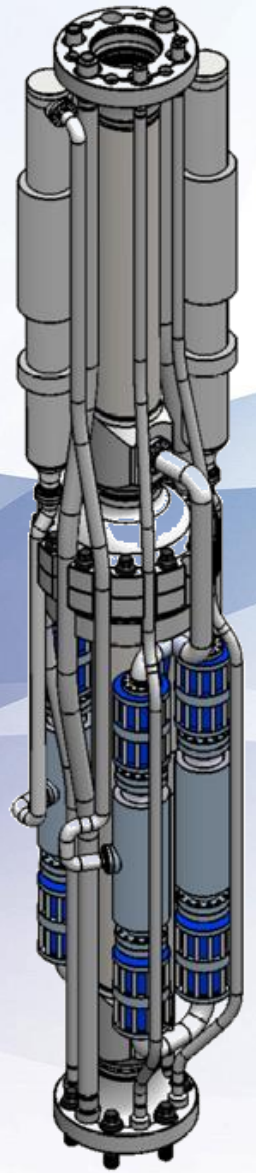
1 x Active MPD Seal

4 x Pump Heads

Single riser joint that drifts through 75.5” rotary table

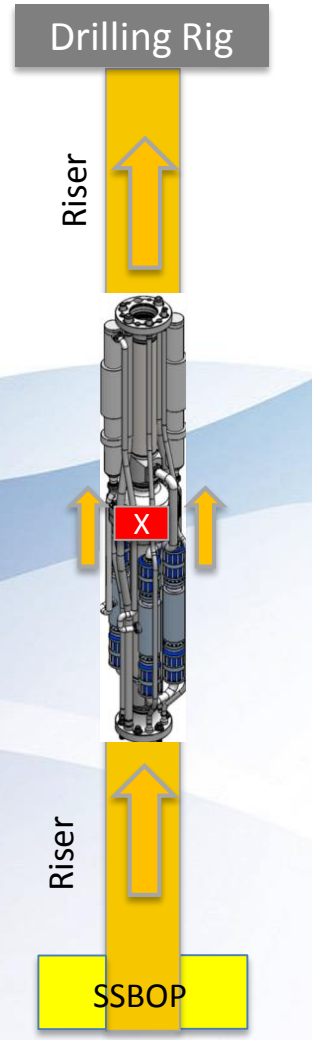
Planned Operating Specification – ECD Control

- Flow Rate: 2000 gpm
- Pressure Control Window: 1000 psi (more possible)
- Development Targets
  - Low Power Requirement – Envisioned to be suitable for older floating drilling rigs
  - Riser pressure control tolerance +/- 15 psi (1 bar)
  - Riser pressure adjustment in < 5 seconds
- Debris size 2”, screen for larger debris
- 2 independent pump systems
- Single riser joint that drifts through 75.5” rotary table (including crossovers and riser peripheral lines), smaller drift possible with additional engineering
- Current installation depth rating is 1640’ [500m] , greater depths possible with additional engineering
- API 6A, API 16A, API 16RCD compliant
- No Drill String Valve required

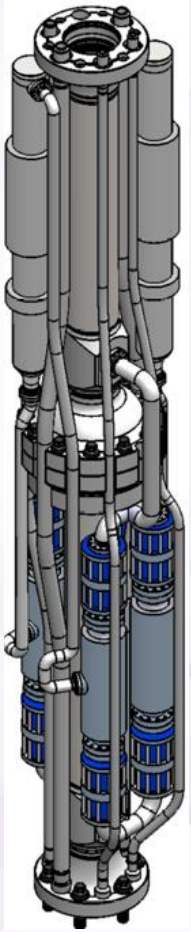


Operational Benefits of the PRS – ECD Control

- Operations conducted with overbalanced safety margin on static mud weight to reduce risk of swabbed in kick
  - Swabbed in kicks are commonly cited as a source of undetected kicks that enter the riser
- In the event of a sudden loss in wellbore circulating friction or failure of the subsea pump or MPD seal, the wellbore is instantly restored to a conventional state – full riser/statically balanced.
- Does not require time for riser refill/depletion on every connection
- Full riser and statically balanced well permits conventional kick detection and conventional static flow check – Enhanced kick detection possible
- Drill String Valve is not required as there is no u-tubing
- 4” eq. ID flow path for contingency drilling with losses (Shut-down PRS and command the Active MPD seal to open)

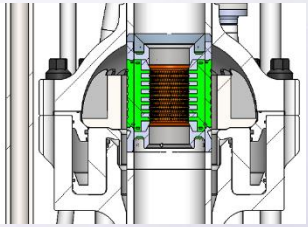


Technology Readiness Level Assessment



Drive Motors

Riser Annular



Seal Sleeve Element

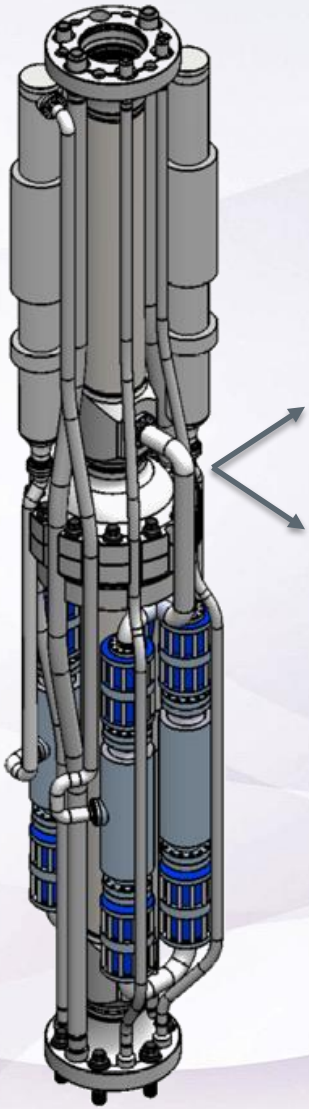
Pump Heads

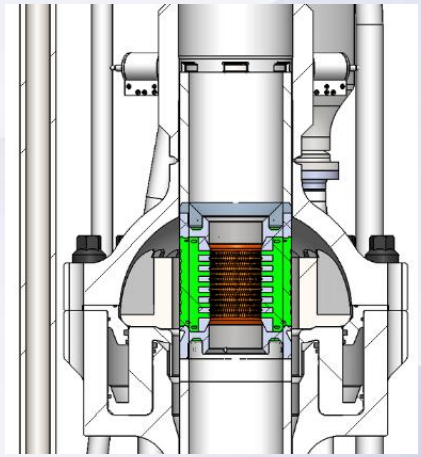
Flowspool and Riser Crossovers

Field Proven Components
Riser Annular – Offshore
Sealing Element – Offshore
Flowspool & Crossovers – Offshore
Pumpheads – Proven in Mining
Electric Drive Motor - Offshore

Novel Features	Development Plan
PRS Configuration	Planned indoor flowloop & offshore prototype test
Operation of pump heads with drive motor	Successful prototype test completed. Next steps above

Single Active Control Device – Subsea Pumping

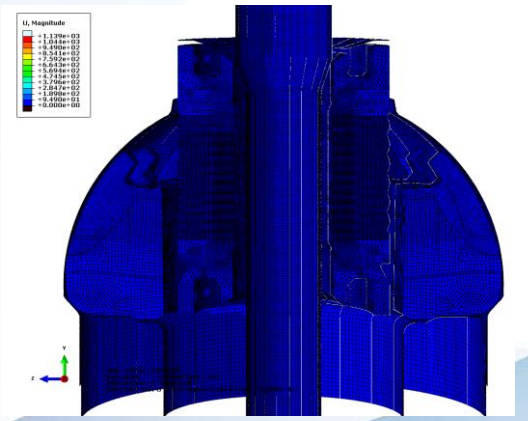




- Active sealing system uses a riser annular to engage a seal sleeve element to seal on drill pipe.
- Sealing integrity is controlled by adjusting annular piston pressure
- Drill pipe rotates relative to static components
- Symmetrical sealing element design. Seals equally from above or below (ASBP or DGD)
- Active Control Device permits remote opening of 4” eq. ID flow path or trip out seal sleeve for full riser bore
- 500 m subsea is a benign environment for MPD Wellbore Seal – Negligible side loading
- Derivative of a 2014, API 16RCD Monogrammed & Field Tested system
  - Static Rating: 3000 psi
  - Dynamic Rating:
    - 1500 psi at 90 RPM
    - 1000 psi at 120 RPM

2nd Gen. Active Control Device - ASBP MPD Operations

- Active pressure system that can be adjusted
  - Uses Annular BOP technology
  - No bearing required
- Specifications
  - 100 hour seal life at 1700 psi / 120 RPM
  - 3.5 MM Equivalent tension per API 16F
  - 2000 psi MAWP
  - Length of 32 ft
  - Weight of 66,500 lbs
  - Integral Auxiliary Lines
  - Deployable through a 60.5” rotary
- Over 5000 hours of testing completed
- Lubrication system for reduced wear of elements

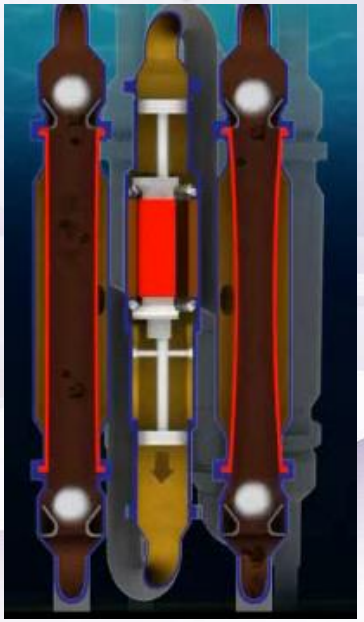


Field Proven Offshore & Lab Tested MPD Sealing Technology

2nd Generation ACD at Houston Test Rig Facility

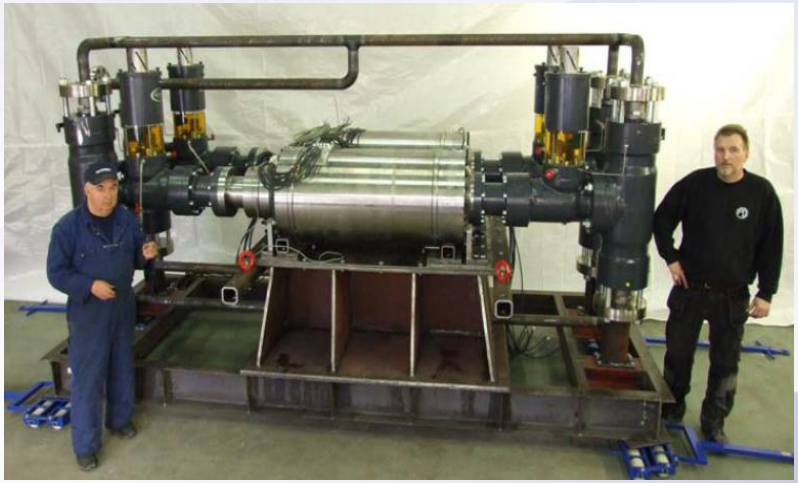
2014 Offshore field deployment
Sealing elements all performed as intended

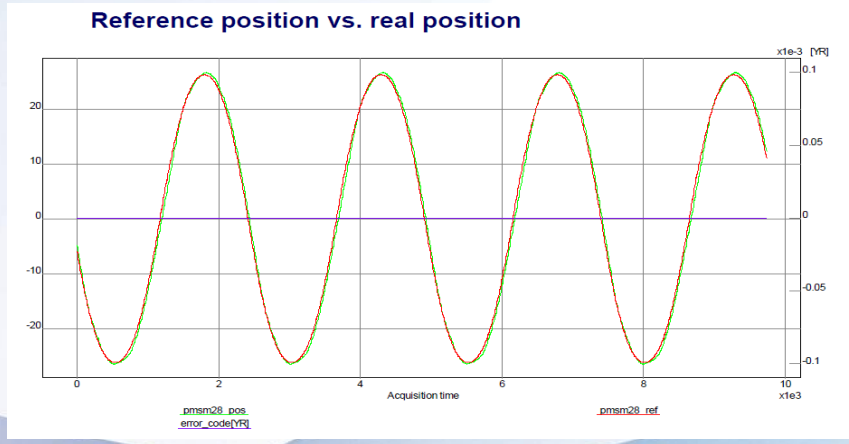
Subsea Hose Diaphragm Mud Pump

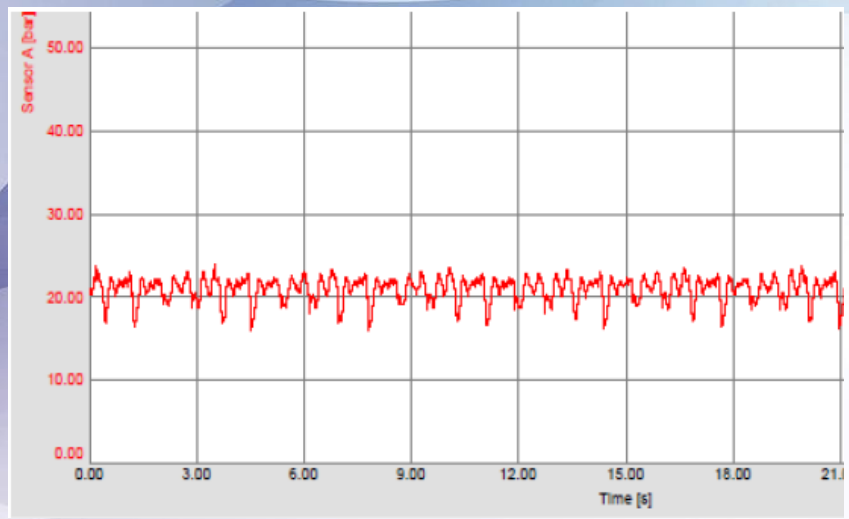


- Hose diaphragm pump heads used in mining industry for 25 years – Slurry and large debris
- Positive displacement pump, high theoretical efficiency
- Old pump drive design modified as slim cylindrical modern electric linear drive in subsea housing
- Drive Motor and Pump heads successfully prototype tested - $2 MM USD investment
- 4 x Hose diaphragm pump w / check valves
- 2 x locally positioned, linear electric drive motors
- The pump system is placed in a balanced, oil filed housing that is rated to be part of the riser system
- Pump diaphragm liners are dual lined, and can be customized for abrasion and chemical resistance
- The pump liners operate with a low differential pressure
- 2” debris size limited by ball and valve seat clearance, larger debris possible with larger housing

Field Proven in Mining & Lab Tested Pump Technology



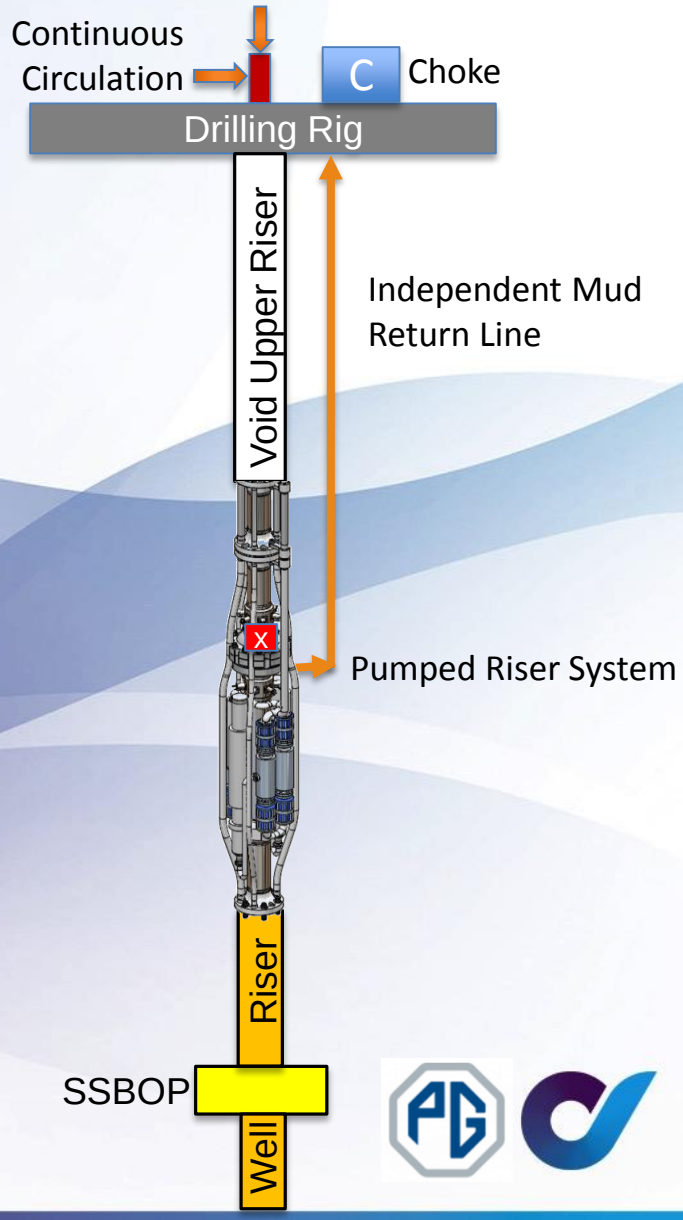




- $2MM Prototype pump to demonstrate drive motors can control pump heads – 1750 psi pump system
- 25 year pump head design - Mining
- Successful test results show predictable stroke position over time demonstrating precision control
- Smooth flow rate and pressure control

Stepping Stone to Full Dual Gradient Drilling

- PRS ECD Control is a stepping stone to Full DGD
  - Compact Design
  - Simple Control System
  - Energy Efficient
- Full DGD envisioned to take place with a dedicated - independent mud return line.
- Continuous circulation recommended with Drill String Safety Valve as back-up
- MPD choke for contingencies
- Next Step: Riserless/seafloor deployment



Calculated Power Consumption - 85% Theoretical Efficiency

ECD Management

Lift	Flow Rate	Power Consumption
200 psi	1500 gpm	175 kw
600 psi	800 gpm	250 kw

Seawater Gradient - DGD

Lift	Flow Rate	Mud Density	Power Consumption
2450 psi	1500 gpm	13 ppg -> 8.6 ppg	1.8 MW
3600 psi	1200 gpm	16 ppg -> 8.6 ppg	2.2 MW

Conclusions

- The combination of a compact positive displacement pump system with an active MPD wellbore seal provides the following benefits:
  - Full riser and statically balanced wellbore
  - Minimizes changes to existing drilling practices
  - Deployed through the rotary table as a standard joint of riser
  - 2 week installation time without modifying existing rig/riser equipment
- The compact design, high power efficiency, and simple control system create an architecture that is suitable to be scaled up to full dual gradient drilling
- PRS Base Model can be run independently or as complimentary technology to ASBP-MPD
- The PRS is comprised of proven technology (Offshore/Mining) which is intended to de-risk the technology development process.
- Full scale offshore testing planned for 2020 with small scale flow loop testing planned in then near future to fully investigate and refine pump control algorithms.

Questions?

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